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**Urban Terrain Building Types, Second Edition
Public Releasable Version**

by Richard Ellefsen and David Fordyce

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Authors' Biographies

Richard A. Ellefsen, Ph.D. is a professor emeritus from the San Jose State University. His field of study has been in geography. Dr. Richard Ellefsen is a recognized expert in the areas of urban morphology and city characterization. He has instituted a classification system for urban terrain that is used currently by the U.S. Government. Dr. Ellefsen's work spans a time period of more than 40 years and has numerous publications to his credit. His publications are considered "primary sources."

David Fordyce is a practicing Mechanical Engineer employed by the U.S. Army Research Laboratory Survivability/Lethality Analysis Directorate at APG. Mr. Fordyce has worked for the U.S. Army for 24 years of which 9 have been for ARL. Mr. Fordyce received his B.S.M.E. from the University of Maryland Baltimore County and his M.S.M.E. from the University of Maryland College Park, concentration in Solid Mechanics. Mr. Fordyce has been working on characterizing the urban environment and weapon effects in urban terrain for the past 12 years.

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1. Need

The structure target is a common element of concern to military planners, weaponeers, battle damage assessors, munition designers, firing platform designers, evaluators, modeling and simulation analysts, and developers of suitable range targets for use in live fire and training exercises. Using a precise and comprehensive set of standard geotypical building descriptions as a baseline eliminates a significant variable in estimating weapon effects. To date, a set of building descriptions has not been available to this community. The U.S. Army Research Laboratory, Survivability/Lethality Analysis Directorate, directed the development of this report. This report provides these descriptions on a worldwide basis using an established and accepted methodology.

The first edition of *Urban Terrain Building Types* was released informally in at a DoD working group meeting held in Vicksburg, MS. The document detailed 40 structure types and regional incidence of occurrence information. During the meeting, a subset of the 40 structure types was chosen by the working group in attendance for developing a more detailed description of the selected structures. The reduced set consists of 14 structure types—7 that have been selected from the mass construction category and 7 from the framed construction category (table 1).

Table 1. Set of 14 structures selected for detail design.

Mass Construction	Framed Construction
Adobe house (UTBT mass 3)	R/C-framed house with brick infill (UTBT framed 12)
Triple brick house (UTBT mass 5)	R/C-framed store/apartment building (UTBT framed 14)
Triple brick Middle Eastern house (UTBT mass 6)	R/C-framed light-clad hotel (UTBT framed 9)
CMU house (UTBT mass 14)	R/C-framed light-clad office (UTBT framed 10)
Box wall apartment (UTBT mass 22)	Central pylon light-clad office (UTBT framed 11)
Box wall hotel (UTBT mass 23)	R/C-framed industrial building with infills (UTBT framed 16)
Brick mosque (UTBT mass 23)	Light steel-framed industrial building with corrugated cladding (UTBT framed 20)

Note: CMU = concrete masonry unit. R/C = reinforced concrete. UTBT = urban terrain building type.

Based on review and input from various DoD organizations, the document was expanded (adding sections on venting, roof characteristics, and 4 additional structures to the original set of 40), made more user-friendly, and submitted to a formal publication process. The second edition of *Urban Terrain Building Types* is the result.

2. Goals

To date, wall and structure target descriptions available for testing and evaluation,¹ analysis, planning, and training² are few in type and may not fit within the urban terrain zone (UTZ) methodology. Some of these targets originated in the Cold War of the 1970s and 1980s and do not reflect the current theater of operations. Further, the targets are not standardized across the services, and specifications do not exist for the target construction. The specific goals of this document are as follows:

1. Provide a set of representative geotypical target building types comprising a comprehensive data set of types and specifications that could be encountered in urban operations activities on a global basis, and reflect appropriate regional variation using an established and accepted methodology.
2. Organize the set of target descriptions into a standardized, manageable, readily transferable, and useful form for use by the urban operations community.
3. Provide a comprehensive data set of information on each building type. The data for each building type are:
 - a. Building exterior shape and dimensions.
 - b. Type of construction method and material characteristics.
 - c. Wall composition and thickness (interior and exterior).
 - d. Venting character and dimensions (doors and windows).
 - e. Interior configurations (room dimensions and room use).
 - f. Regional incidence of building-type occurrence (where in the world does the type occur).

3. Approach

Responding to the statement of need and goals discussed earlier, the approach taken was to develop a broad base of information on the physical and functional characteristics of urban terrain building types (UTBTs). Information is organized by primary construction type (mass and framed), specific method of construction and materials used, and details on building

¹International Test Operating Procedure 5-2-503, Human Engineering Laboratory Technical Memorandum 30-78, STANAG 4536.

²McKenna MOUT, Joint Readiness Training Center, and others.

interiors. The building representations and examples in this report are geotypical in nature, i.e., buildings of a common type in a geographical region or structures that are constructed using a common construction method. Usually, these structures are ubiquitous in the geographical area considered. Geospecific building representations describe a particular building in a particular location and are not the subject of this report. A total of 44 UTBTs are presented in the catalog section of the report. This catalog consists of 243 separate plates showing various characteristics and properties. The plates range from 5 to 12 for each building type (the number of plates reflecting levels of complexity).

Several factors were considered when selecting the 44 building types, such as ascertaining that all major worldwide structure types are represented and that the selection met the DoD working group's purpose to present to the broader urban operations community building types that match the interests of a wide variety of users engaged in testing, modeling and simulation, combat development, and weapons/munitions development.

4. Method

The building types presented in this report (see tables 4 and 5) come from canvassing the open literature covering international architecture and structural engineering. Examples of these building types were photographed on numerous field expeditions to 71 cities in 41 countries over an elapsed 50-year period. Many of these photographs serve as examples for users and as the source from which measurements were taken, e.g., venting dimensions. Window patterns also serve as an exterior clue to floor plans. The view of building materials provides valuable keys to construction, e.g., the specific bonding type of brick walls.

Almost all buildings used in the report were photographed by Richard Ellefsen during the course of numerous study trips abroad. Photographs of Koblenz, Germany, were taken by David Fordyce.

Other details, such as floor plans, were taken from occurrences in the literature. Sources used were published books and information from the Web. An especially valuable Internet source is the World Housing Encyclopedia Report (www.world-housing.net) maintained by the Earthquake Engineering Research Institute. Data on building height and spatial placement in an urban setting were derived from open-source aerial photographs and high-resolution satellite data, now available on the Internet for virtually all major urban areas in the world.

An integrated collation of the building types was performed according to the UTZ methodology found in section 13 of this report.

5. Introduction to Tables 2 Through 6

In this report, building types are linked to appearances in UTZ. The UTZ classification system is presented in section 13 of this report. Table 2 provides the urban morphology categories that comprise the UTZ classification system developed by the primary author. The cross-indexing between building types and the UTZ system is presented as table 3. Reference to table 2 and the UTZ plates found in the UTZ methodology section of this report will serve to enhance understanding of both the building types and the UTZs. All but one UTZ plate has an oblique air-photo example (on the right-side panel of each plate). Choosing examples from many cities in the world was a fairly simple task thanks to the universality of the classification system. This serves to confirm that both the cause and the response to urban/economic/social stimuli are universal, even when countries vary widely in their form of government. (For example, the People’s Republic of China’s approach in their large cities does not differ from capitalistic countries.)

Tables 4–6 form an integral trio. Tables 4 and 5 serve the purpose of providing an index (see page numbers in the right column referring to the plate location for each building type in the catalog). These two tables indicate the primary type of construction (mass or framed), the more specific methods of construction (e.g., unit masonry), and the discrete type of building material of which each building type is made (e.g., kiln-dried brick). That some groups have more entries than others expresses the incidence of building-type occurrence on a global basis. For instance, only two entries are listed for stone buildings, as such structures are uncommon (at least, all-stone structures as opposed to those with a stone veneer over other forms of construction). Kiln-dried brick construction and various forms of infill wall associated with framed buildings have nine and eight entries, reflecting their broad worldwide occurrence.

Table 2. Current UTZ classification system.

Attached Buildings UTZs		Detached, Closely Spaced Buildings UTZs		Detached, Widely Spaced Buildings UTZs	
A1	Attached commercial buildings	Dc1	Detached, closely spaced high-rise office buildings	Do1	Shopping centers with parking lots
A2	Attached hotels and apartment buildings	Dc2	Detached, closely spaced apartment buildings	Do2	Detached, widely spaced apartment buildings
A3	Attached houses	Dc3	Detached, closely spaced houses	Do3	Detached, widely spaced houses
A4	Attached industrial /storage buildings	Dc4	Detached, closely spaced industrial/storage buildings	Do4	Detached, widely spaced industrial/storage buildings
A5	Attached commercial buildings along arterial streets	Dc5	Detached, closely spaced commercial buildings	Do5	Detached, widely spaced commercial buildings
—	—	Dc6	Detached, closely spaced administrative/cultural buildings	Do6	Detached, widely spaced administrative/cultural buildings

Note: UTZ = urban terrain zone.

Table 3. Common locales by UTZs for building types.

Target Type (UTBT Designation)	Urban Terrain Building Type	UTZs Where Type Is Common
Mass 1-1	Stone house	Old A1
Mass 2-1	Stone institutional	A1
Mass 3-1	Adobe house	Developing Nation A3
Mass 4-1	Mud brick single-floor store	Developing Nation A1
Mass 5-1	Triple brick house	A3, Dc3
Mass 6-1	Triple brick Middle Eastern house	A3, Dc3
Mass 7-1	Brick row house	A3
Mass 8-1	Brick apartment building	A2, Dc2
Mass 9-1	Brick hotel	A1, A2
Mass 10-1	Brick office	A1
Mass 11-1	Brick store	A1, A5
Mass 12-1	Brick mosque	A1, A3, Dc3, Dc6, Do6
Mass 13-1	Brick industrial/storage	A4, Dc4
Mass 14-1	CMU house	Dc3, Do3
Mass 15-1	CMU store	A5, Dc5
Mass 16-1	CMU industrial/storage	Dc4, Do4
Mass 17-1	Brick-over-block house	A3, Dc3, Do3
Mass 18-1	German brick-over-block house	A3, Dc3, Do3
Mass 19-1	Unreinforced apartment with masonry cover	A2
Mass 20-1	Retail store	A1, Dc5, Do1, Do5
Mass 21-1	Tilt-up industrial/storage	Do4
Mass 22-1	Box-wall apartment building	Do2
Mass 23-1	Box-wall hotel	A1, A2, Do5
Framed 1-1	Half-timbered wood house	A1, A3
Framed 2-1	Half-timbered wood store	A1, A5
Framed 3-1	Wood-framed house	Dc3, Do3
Framed 4-1	Brick veneer house	Dc3, Do3
Framed 5-1	Wood-framed store	A5, Dc5
Framed 6-1	Heavy-clad hotel	A1, Dc1, Do1
Framed 7-1	Heavy-clad office	A1, Dc1, Do1
Framed 8-1	Light-clad apartment building	Do2
Framed 9-1	Light-clad hotel	A1, Dc1, Do1
Framed 10-1	Light-clad office	A1, Dc1, Do1
Framed 11-1	Central pylon office building	Dc1, Do1
Framed 12-1	Brick infill house	A3, Dc3
Framed 13-1	Terra cotta infill house	A3, Dc3
Framed 14-1	Store/apartment	A5, Dc5
Framed 15-1	Brick infill store/office	A5, Dc5
Framed 16-1	Industrial/storage with CMU infill	A4, Dc4, Do4
Framed 17-1	Industrial/storage with terra cotta infill	A4, Dc4, Do4
Framed 18-1	Industrial/storage with brick infill	A4, Dc4, Do4
Framed 19-1	School with brick infill	Do6
Framed 20-1	Light steel-framed industrial storage	Dc4, Do4
Framed 21-1	Light steel-framed double-industrial storage	Dc4, Do4
44 Total Types		

Note: UTBT = urban terrain building type. UTZ = urban terrain zone.

Table 4. Forty-four universal UTBTs by method of mass construction and by function.

Table of Structures and Index to Building Types						
Principal Construction Method	Sub Type	Building Material	Function	UTBT Title	UTBT I.D. No.	UTBT Page No.
Mass construction	Buildings that use masonry units	Stone	Residential	Stone house	Mass 1	50
			Institutional	Stone institutional	Mass 2	55
		Sun-dried mud brick (adobe)	Residential	Adobe house	Mass 3	61
			Retail	Single floor store	Mass 4	68
		Kiln-fired brick	Residential	Triple brick house	Mass 5	76
				Middle Eastern house	Mass 6	84
				Row house	Mass 7	92
				Brick apartment building	Mass 8	100
			Hotel	Brick hotel	Mass 9	106
			Office	Brick office	Mass 10	111
			Store	Brick store	Mass 11	117
			Institutional	Brick mosque	Mass 12	122
			Industrial	Industrial/storage	Mass 13	127
		CMU	Residential	CMU house	Mass 14	132
			Retail	CMU store	Mass 15	138
			Industrial	CMU industrial/storage	Mass 16	143
		Brick over block	Residential	Brick over block	Mass 17	148
				German brick over block	Mass 18	153
		Concrete	Poured in place	Residential	Unreinforced apartment with masonry cover	Mass 19
	Retail			Retail store	Mass 20	166
	Tilt-up		Industrial	Industrial/storage	Mass 21	171
	Box-wall principle (panel)		Residential	Apartment building	Mass 22	177
			Hotel	Hotel	Mass 23	189

Note: UTBT = urban terrain building type. CMU = concrete masonry unit.

The function column gives the use of each building type, in systematic order, beginning with residential (houses and apartment buildings) and followed by hotels, offices, retail stores, institutional buildings, and industrial/storage buildings. These general classes are in accord with the widely accepted land-use classes seen in such U.S. government documents as the *Standard Land Use Coding Manual*.

Table 6 expands upon the entries in tables 4 and 5. It is designed to provide users with a quick, comprehensive reference guide to a variety of physical UTBT properties covered in this report. For each building type, data are provided on wall dimensions and materials; floors; roof sizes and materials; venting; and room dimensions. All of these data items refer to and are derived from detailed data presented in the 243 plates (for 44 distinctive UTBTs) in the catalog.

Table 5. Forty-four universal UTBTs by method of framed construction and by function.

Table of Structures and Index to Building Types						
Principal Construction Method	Sub Type	Building Material	Function	UTBT Title	UTBT I.D. No.	UTBT Page No.
Framed construction	Wood post and lintel	Half-timbered	Residential	House	Framed 1	196
			Retail	Store	Framed 2	201
		Light wood frame	Residential	Wood-framed house	Framed 3	207
				Brick veneer house	Framed 4	214
			Retail	Store	Framed 5	219
	Steel or R/C frame	Steel-framed heavy clad	Hotel	Hotel	Framed 6	224
			Office	Office	Framed 7	233
		Steel- or R/C-framed light clad	Residential	Apartment building	Framed 8	243
			Hotel	Hotel	Framed 9	248
			Office	Office	Framed 10	257
			Central pylon office	Office	Framed 11	263
		R/C-framed with infill walls	Residential	Brick infill house	Framed 12	270
				Terra cotta infill house	Framed 13	282
			Mixed residential /commercial	Store/apartment	Framed 14	290
			Retail	Brick infill store/office	Framed 15	298
			Industrial	Industrial/storage with CMU infill	Framed 16	303
				Industrial/storage with terra cotta infill	Framed 17	309
				Industrial/storage with brick infill	Framed 18	315
	Institutional	School with brick infill walls	Framed 19	321		
	Very light steel framed	Industrial	Industrial/storage	Framed 20	327	
			Double industrial/storage	Framed 21	332	

Note: UTBT = urban terrain building type. R/C = reinforced concrete. CMU = concrete masonry unit.

Table 6. Building properties table.

Building Type Mass Construction	Building I.D.	Location	External Wall Thick. (cm)	External Wall Masonry Unit Size (cm)	Interior Wall Thick. (cm)	Interior Wall Masonry Unit Size (cm)	Interior Wall Material	Floor Material	Roof Shape	Roof Material	Roof Thick. (cm)	Mean Percent Window Front Wall	Mean Percent Doors Front Wall	Mean Window Size (m ²)	Mean Room Size (m ²)
Stone house	Mass 1	Europe	40	Varied	20	Varied	Stone	Wood	Pitched	Tile	2	7.8	4.1	1.2	16.0
Stone institutional building	Mass 2	Europe	40–100	Varied	Varied	Varied	Stone	Stone	Pitched	Tile	4	10.3	6.2	2.2	125.0
Adobe house	Mass 3	Southwest Asia	80	40 × 26	80	40 × 26	Adobe	Adobe	Flat/domed	Mud/wattle	10	7.8	5.9	1.2	19.8
Adobe store	Mass 4	Southwest Asia	48	30 × 15	48	30 × 15	Adobe	Adobe	Flat	Mud/wattle	10	6.9	6.2	1.9	40.0
Triple brick house	Mass 5	World	36	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	13.3	6.9	1.2	12.7
Middle Eastern house	Mass 6	SWA	34.5	11 × 22	34.5	11 × 22	Brick	Concrete	Flat	Concrete	10	0.0	6.2	0.0	24.8
Row house	Mass 7	World	36	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	12.1	6.9	2.4	17.7
Brick apartment building	Mass 8	World	48–96	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	13.1	10.5	2.4	19.3
Brick hotel	Mass 9	World	48–96	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	16.4	11.8	1.9	17.8
Brick office	Mass 10	World	48–96	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	15.0	2.6	2.1	26.7
Brick store	Mass 11	World	36	11.5 × 23	23	11.5 × 23	Brick	Wood	Pitched	Tile	2	20.8	20.8	1.9	20.0
Brick mosque	Mass 12	Southwest Asia	60	11.5 × 23	None	NA	NA	Tile	Flat/domed	Brick	10	6.3	1.1	NA	125.0
Brick industrial/storage	Mass 13	World	36	11.5 × 23	23	11.5 × 23	Brick	Concrete	Pitched	Tile	2	18.1	2.6	3.8	360.0
CMU house	Mass 14	World	20	20 × 40	10	10 × 40	CMU	Concrete	Pitched	Tile	2	10.1	7.5	1.2	11.2
CMU store	Mass 15	World	20	20 × 40	20	20 × 40	CMU	Concrete	Pitched	Composite	1	48.7	25.5	1.9	16.0
CMU industrial/storage	Mass 16	World	20	20 × 40	10	10 × 40	CMU	Concrete	Pitched	Steel	0.2	18.1	2.6	1.5	78.5
Brick/block house	Mass 17	North America	32.5	Combination ^a	20	20 × 40	CMU	Concrete	Pitched	Tile	2	13.3	6.4	1.2	13.3
German brick/block house	Mass 18	Europe	35.5	Combination ^b	23	23 × 46	CMU	Concrete	Pitched	Tile	2	13.3	5.6	1.2	15.5
Concrete apartment	Mass 19	Southwest Asia	45	Combination ^c	15	NA	Concrete	Concrete	Flat	Concrete	10	13.1	10.5	2.4	13.5
Concrete store	Mass 20	World	20	Non unit	10	Stud	Steel/wood	Concrete	Flat	Concrete	10	16.3	7.5	1.9	504.0
Tilt-up industrial	Mass 21	North America	20	Non unit	10	Stud	Steel/wood	Concrete	Flat	Concrete	10	5.4	13	3.8	280.0
Box wall apartment	Mass 22	Europe	20	Non unit	16	NA	Concrete	Concrete	Flat	Concrete	10	24.2	2.4	3.0	16.3
Box wall hotel	Mass 23	North America	15	Non unit	15	NA	Concrete	Concrete	Flat	Concrete	10	39.4	1.1	4.0	28.0

^aCombination: CMU block (20 cm) and brick (11.5 cm). ^bCombination: CMU (German, 25 cm) and brick (11.5 cm). ^cCombination: poured concrete (30 cm) plus stone (15 cm).
NA = not applicable.

Table 6. Building properties table (continued).

Building Type Mass Construction	Building I.D.	Location	External Wall Thick. (cm)	External Wall Masonry Unit Size (cm)	Interior Wall Thick. (cm)	Interior Wall Masonry Unit Size (cm)	Interior Wall Material	Floor Material	Roof Shape	Roof Material	Roof Thick. (cm)	Mean Percent Window Front Wall	Mean Percent Doors Front Wall	Mean Window Size (m ²)	Mean Room Size (m ²)
Half-timbered house	Framed 1	Europe	15	Non unit	15	Stud	Wood	Wood	Pitched	Tile	2	9.1	2.4	1.9	18.2
Half-timbered store	Framed 2	Europe	15	Non unit	15	Stud	Wood	Wood	Pitched	Tile	2	12.0	5.1	1.9	32.0
Wood-framed house	Framed 3	Regional	14–24	Non unit	12	Stud	Wood	Wood	Pitched	Tile	2	9.1	10.5	1.9	14.3
Brick veneer house	Framed 4	Regional	24	11.5 × 23	12	Stud	Wood	Wood	Pitched	Tile	2	9.1	10.5	1.9	14.3
Wood store	Framed 5	Regional	12	Non unit	12	Stud	Wood	Wood	Pitched	Tile	2	0.0	70	0.0	30.0
Steel-framed hotel	Framed 6	World	35.5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	18.3	2.8	2.4	21.6
Steel-framed office	Framed 7	World	35.5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	17.6	0.8	24.4	74.2
Light clad apt	Framed 8	World	2–5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	21.9	0.6	2.7	16.2
Light clad hotel	Framed 9	World	2–5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	23.9	1.3	2.4	28.0
Light clad office	Framed 10	World	2–5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	33.7	0.6	26.7	112.0
Central pylon office	Framed 11	World	2–5	Non unit	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	33.7	0.8	26.7	264.0
Brick infill house	Framed 12	World	23	11.5 × 23	11.5	11.5 × 23	Brick	Concrete	Flat	Concrete	10	13.9	2.9	1.9	11.6
Terra cotta infill house	Framed 13	World	25	25 × 40	11.5	11.5 × 23	Brick	Concrete	Flat	Concrete	10	10.1	2.9	1.9	11.6
CMU infill store/apartment	Framed 14	World	20	20 × 40	10	10 × 20	CMU	Concrete	Flat	Concrete	10	13.4	3	2.7	40.0
Brick infill store	Framed 15	World	23	11.5 × 23	12	Stud	Steel/wood	Wood	Flat	Concrete	10	20.8	1.8	3.6	27.0
CMU infill industrial/storage	Framed 16	World	20	20 × 40	20	20 × 40	CMU	Concrete	Pitched	Steel	0.2	2.5	9.1	2.0	592.0
Terra cotta infill industrial/storage	Framed 17	World	25	25 × 40	12	Stud	Steel	Concrete	Pitched	Steel	0.2	2.5	9.1	2.0	592.0
Brick infill industrial/storage	Framed 18	World	23	11.5 × 23	12	Stud	Steel/wood	Wood	Flat	Concrete	10	2.5	9.1	2.0	592.0
Brick infill school	Framed 19	World	23	11.5 × 23	12	Stud	Steel/wood	Concrete	Flat	Concrete	10	20.9	0.7	11.5	68.6
Light-framed industrial/storage	Framed 20	World	0.2	Non unit	None	Stud	Steel/wood	Concrete	Pitched	Steel	0.2	4.4	7.4	8.0	105.0
Double light-framed industrial/storage	Framed 21	World	0.2	Non unit	None	Stud	Steel/wood	Concrete	Pitched	Steel	0.2	4.4	5.7	2.5	950.0

Note: 12 cm includes air space between studs. Non unit: wall not composed of masonry units. Regional: Northwest Europe, North America, Japan, tropics.

6. An Overview of the UTBT Catalog by Method of Construction and by Function

The UTBT catalog is organized based on a melding of both morphology (the physical characteristics of buildings) and function (a building's use). Knowledge of both are essential to urban operations in order to know the arrangement, shape, and dimensions of a building's interior as well as its setting in the urban environment.

Morphology is more important than function considering that the battlefield's physical aspects at the beginning of urban operations during a conflict far outweigh the building's functions prior to the start of the conflict. Here, emphasis on morphology is intended to counter the literature's often overly generalized focus on function alone, e.g., industry, retail, or residential.

While the broader term "urban morphology" comprises all physical aspects of a city (ranging from street dimensions, pattern, and trafficability to other non-built-upon surface space, buildings, and monuments), this document focuses on the morphology of buildings.

The primary forms of building construction are mass and framed. A major distinction is made between mass construction—where walls have to be stout as they need to bear both live and dead loads of walls, floors, and roof—and framed construction where it is the frame that bears all loads, allowing walls to be thin and lightweight. Figure 1 is used here to provide a basic organization of building construction types.

For mass construction, the primary components are unit masonry and concrete. The former refers to walls built with units, i.e., stone, adobe, brick, and CMUs. Concrete walls are made by pouring the material into forms where it hardens into walls and other shapes. A CMU wall, when grout fills cavities in the blocks, is, in effect, a concrete wall.

Framed construction differences are based on the type of frame being employed, e.g., wood, steel, or reinforced concrete. The catalog outlines both frame materials and configuration, and cladding- and infill-material characteristics.

There are some exceptions to the generalized construction types listed in figure 1 whose emphasis is on wall vulnerability. Construction of some buildings employs features of both mass and framed construction. Commonly seen forms of construction are (1) use of a mass construction foundation on which sits a framed structure (figure 2); (2) a mass-construction (reinforced concrete) end wall of a high-rise steel-framed building (figure 3); (3) a shear wall in the basement of a framed structure (figure 4); and (4) a wood-framed building resting on a reinforced concrete base (figure 5). Another example is the central pylon type of construction for some high-rise framed buildings (see section 12, framed 11-1) which uses a mass construction reinforced-concrete central unit (a pylon) onto which frame members are attached.

An everyday U.S. example is that of a wood-framed house or other small building supported by a concrete perimeter foundation.

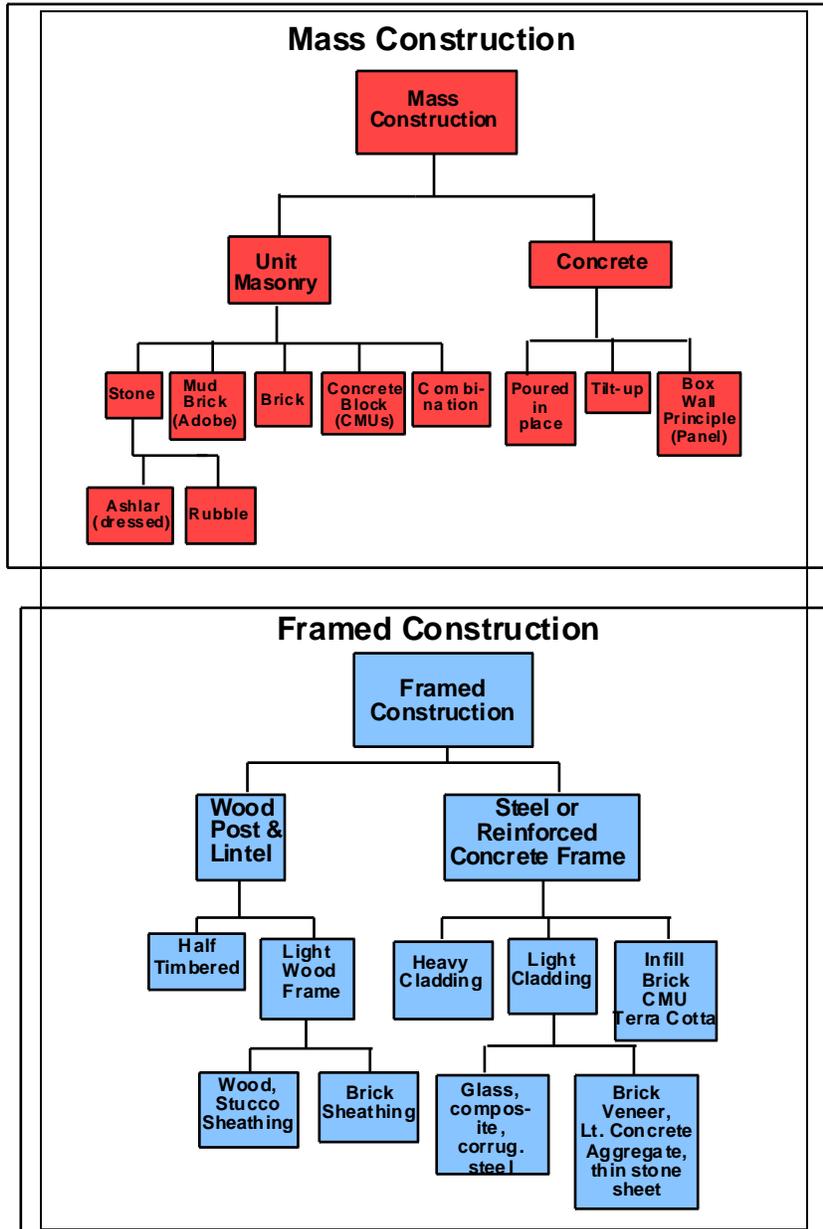


Figure 1. Mass construction (red) is intended to imply buildings that have walls that bear significant weight (both dead and live loads), i.e., “load-bearing walls.” Framed construction (blue) indicates structures in which a frame carries the required loads.



Figure 2. A half-timbered frame house resting on a stone ground floor.



Figure 3. The reinforced concrete end wall of a steel-framed high-rise office building.



Figure 4. Reinforced concrete shear walls in the basement parking area of a framed building while under construction.



Figure 5. Wood-framed structure being built upon a reinforced concrete base. This is the same structure as in figure 4, at a more advanced state.

The following comprehensive list (table 7) groups universal building materials employed in each type of construction. Almost all are represented in the catalog (with the exception of infrequently occurring types, e.g., a log load-bearing wall [log cabin]).

Table 7. Comprehensive list of universal building materials in mass and framed construction.

Mass Construction	
Formed, Shaped Material	Unit Masonry
Concrete Poured in situ or off-site Without reinforcement With reinforcement With steel rebars With webbing	Stone Rubble (natural, irregular shape) Ashlar (shaped or dressed) Brick Mud brick (adobe) Kiln-dried brick Triple brick Quadruple and more brick CMUs Structural terra cotta Brick and block (see U.S. Army Human Engineering Laboratory Technical Memorandum 30-78) Poured-in-place concrete with pilasters Stone over concrete Stucco over brick CMU with brick veneer (brick over block) Log load-bearing wall
Framed Construction	
Wood Framed	Steel of R/C Framed
Post and beam With infill walls Wattle Balloon and platform Siding Boards Brick Stucco	Light-steel frame Corrugated sheathing Steel Asbestos Cladding Heavy clad Brick Stone Concrete Terra cotta Light clad Glass Foam concrete Aluminum Sheet stone Fiberglass Unspecified R/C with infill walls CMU Brick Terra cotta R/C mass central pylon With steel columns and beams

Note: CMU = concrete masonry unit. R/C = reinforced concrete.

Organizing the catalog's 44 building types by function (but grouped under construction types) yields the following list (table 8):

Table 8. Building types by function grouped under construction types.

Residential (Mass Construction)
Stone house
Triple brick house
Middle Eastern house
Row house
Brick apartment
CMU house
Brick over block
Unreinforced apartment with stone facing
Residential (Framed Construction)
Half-timbered house
Light wood-framed house with wood siding
Light wood-framed house with brick veneer
R/C-framed light-clad apartment building
R/C-framed with brick infill house
Hotels (Mass Construction)
Brick hotel
Box-wall principle apartment building
Hotels (Framed Construction)
Steel-framed heavy-clad hotel
R/C-framed light-clad hotel
Offices (Mass Construction)
Brick office
Offices (Framed Construction)
Steel-framed heavy-clad office building
R/C-framed light-clad office building
Central pylon office building
Retail (Mass Construction)
Mud brick store
Brick store
CMU store
Poured-in-place concrete store
Retail (Framed Construction)
Half-timbered store
Light wood-framed store
R/C-framed brick infill store
Industrial (Mass Construction)
Brick industrial/storage building
CMU industrial/storage building
Tilt-up industrial/storage building
Industrial (Framed Construction)
CMU infill wall industrial/storage building
Terra cotta infill wall industrial/storage building
Very light steel-framed industrial/storage building
Very light steel-framed double industrial/storage building
Institutional (Mass Construction)
Stone church
Brick mosque
Institutional (Framed Construction)
R/C-framed with brick infill wall school

Note: CMU = concrete masonry unit. R/C = reinforced concrete.

7. Catalog Organization

The catalog body consists of a series of four groups of plates for each of the 44 UTBTs. Plate 1 consists of just a single entry (see figure 6). Plate groups 2, 3, and 4 contain from 5 to 12 detailed plates. The number varies with the building type's complexity.

- Plate 1: Place of the building type among major world types.
 - Plate group 2: Elevation. Common building elevations for the type, including venting and roof types.
 - Plate group 3: Floor Plan. Detailed floor plans for each of the 44 types, including hypothetical projectile paths and the interior walls encountered.
 - Plate group 4: Construction Features. Type and dimensions of materials and method of construction.
-

8. Plate 1: Place on the Building Construction Chart

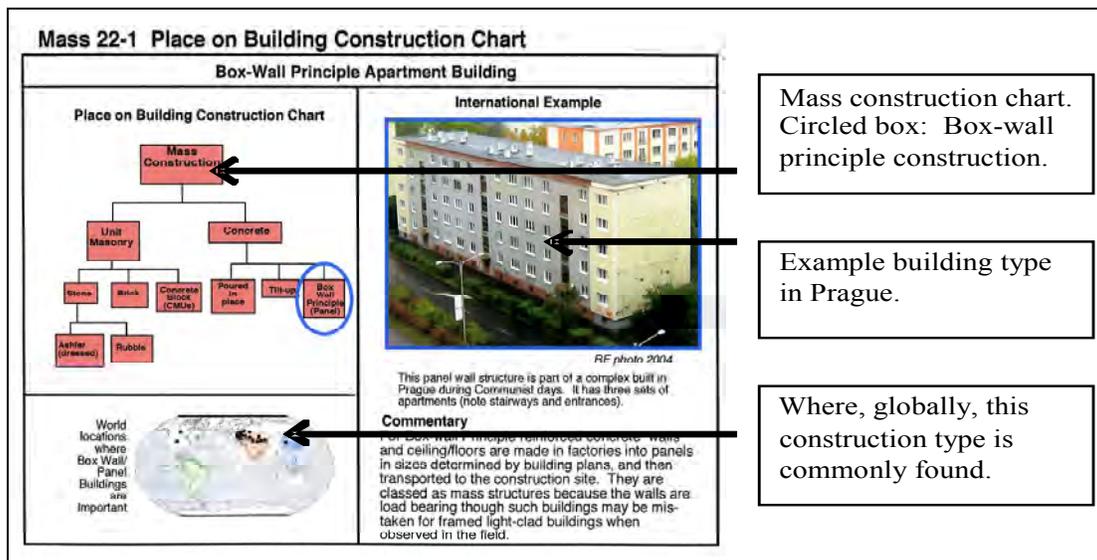


Figure 6. Place on the building construction chart.

This example of a plate 1 (figure 6) begins the series of plates for each UTBT and can be seen in full size as catalog plate 22. Each plate 1 (of 44) consists of the type of construction (circled on the chart), an international photo example, global occurrences of the construction type, and an explanatory commentary.

9. Plate Group 2: Elevation

Profile drawings (elevations) have long been used by architects to demonstrate a planned project for clients. These show window and door placement and, at scale, record venting and other dimensions. All elevations are tied to floor plans. In the catalog, as many elevations as necessary are given for each building type. If front and rear are identical, only one elevation appears. If front, rear, and sides vary, all elevations are shown. Detailed examination and analysis of venting (as depicted in the elevation plates) and roofs (also appearing in the elevation plates) leads to findings as given in the following pages.

9.1 Venting: Windows and Doors

The term venting comprises windows and doors. Venting, in addition to allowing the passage of air through a building, provides lighting, ingress/egress (persons and, in some cases, vehicles), fire safety, and, where appropriate, display of goods or information. Measurements of both windows and doors by building type are included here, shown both separately and in aggregation. See the appendix for 132 measured venting types.

In response to concerns from the urban operations community, the following building characteristics are included in the catalog:

1. Representatives of all UTBTs are measured.
2. Major function types are covered (e.g., residential, commercial, and industrial).
3. Representative buildings from throughout the world are offered.
4. Distinction is made between building elevations, front, back, and side, considering that the number and distribution of windows on commercial buildings in cities are far greater on the front than the rear. Often, when buildings are attached (a UTZ grouping), abutted buildings have no side wall venting at all.
5. Building setting (location with UTZs) is important when considering buildings as artillery targets susceptible to air attacks.
6. Differences between the ground floor and upper floors are also considered. Except for some unusual circumstance, doors can be only at ground-floor level. Accordingly, the proportion of door openings to total exterior wall area in tall buildings is quite small.

9.1.1 Building Construction Type Differences (Mass vs. Framed)

Inherent and essential differences in venting result from the restricting limitations present in mass buildings but not occurring in framed construction. Mass buildings, drawing their support and integrity from the strength and thickness of their load-bearing outer walls—thus having the ability to support the dead load of wall, floor, and roof, plus the live loads of humans and materials—cannot afford to have wall integrity diminished by windows without certain principles being followed. First, windows and doors must be aligned vertically, leaving the undisturbed wall space between to support loads. Second, integrity reduction caused by the window opening must be replaced with some support, such as a lintel above the window (its load being distributed on both sides of the window), or with an arch above the window (both are, in effect, bridges across openings in the wall). Third, the corners of mass buildings cannot have windows, for it is at the corners with their right-angle joining that the mass buildings are the strongest and are able to carry much of the total load. The result is that mass buildings will have a smaller proportion of their walls devoted to windows than will framed buildings.

Framed buildings, where all loads are supported directly by columns or directed to the columns by beams, can have as much wall space devoted to windows as the building designer chooses. In some instances, virtually all exterior walls could be of glass, though requirements of a building's function normally dictate otherwise. Considering that frame members of these buildings bear all loads, while walls (cladding or infill) bear no loads, windows can be placed anywhere on the building's exterior walls, even at the corners. They do not need to be aligned vertically and may be of any size, shape, or variety, as is often called for by the architect to achieve aesthetic effects.

Recognizing these characteristics, this report groups all venting data first by major building construction type (mass vs. framed) and then by generalized function.

9.1.2 Generalizations on Windows and Doors Relative to Building Function

Used in the study are the building functions of houses, apartments, hotels, offices, industrial/storage, and, in the case of mass construction buildings, a class called large masonry structures (churches, mosques, and some institutional buildings).

Window size, shape, and pattern respond to a building's function. Thus:

- Retail stores have large windows to display merchandise.
- Storage buildings have few or no windows.
- Office buildings are designed to provide natural light to workers.
- Industrial buildings have various lighting requirements. Some prefer abundant natural light for factory workers while other industrial functions require little or no natural light.
- Apartments require that each room have some natural light (sometimes by employing a light well) for air circulation, light for activities, and safety.

- Houses have the same requirement. In recent years in advanced countries, window openings are restricted by building code for energy conservation purposes.

The opportunities and constraints imposed by building construction type to match these basic needs are discussed in detail in following sections.

9.1.3 Venting Measurements

Key venting items are window and door dimensions; the proportion of wall space occupied by venting; and forms and patterns of venting seen in various morphological and functional building types. Data were obtained by making measurements from a broad range of buildings (located in urban areas throughout much of the world) in 71 cities located in 41 separate countries. Specifics are noted in table 9.

Also considered in the selection of measured buildings was the age of structures. Some are several centuries old, some are of recent vintage, and several are under construction (where construction method is revealed).

Buildings of the same function, e.g., hotels, in both mass and frame construction are represented. This shows that the same function may have similar window patterns in either mass or framed construction. In another observation, the lack of constraint on window placement and size in framed buildings results in very large window areas, e.g., modern high-rise glass-curtain wall buildings, structures that are the mode in redeveloped city core areas, and buildings in clusters at major airports and in other outlying commercial developments.

9.1.4 Data Organization

Venting measurements were made using photographs of buildings in cities throughout much of the world. In addition to the 44 buildings shown in the catalog plates, another 49 are incorporated and are referred to collectively as the world set. Data from the 44 plates record venting on all sides of a building. Only front wall venting is measured for the additional 49 plates. Data, organized by building construction type and function, appear in table 10. Combined figures for doors and windows appear in table 11. Separate tables provide data on components of tables 10 and 11, and are listed as:

- Table 11: Percent windows of mass and framed construction buildings in the world set.
- Table 12: Percent windows for specific building types of mass construction buildings in the world set.
- Table 13: Percent windows for specific building types of framed construction in the world set.
- Table 14: Mean window dimensions by groups for mass and framed construction types.

The complete set of window measurements (83 mass construction and 59 framed construction buildings) appears in the appendix.

Table 9. Cities and countries where venting measurements were taken.

Region	Country	Cities
Europe	Andorra	Andorra
	Austria	Linz, Vienna
	Czech Republic	Prague
	Finland	Helsinki
	France	Chartes, Limoges, Paris, Reims
	Germany	Berlin, Braunschweig, Bremen, Falkenberg, Hammelburg, Koblenz, Salzgitter
	Gibraltar	Gibraltar
	Greece	Athens
	Hungary	Budapest
	Italy	Rome, Castellina
	Netherlands	Rotterdam
	Norway	Stavanger
	Portugal	Lisbon
	Spain	Seville
	Sweden	Helsingborg, Norrkoping, Uppsala
United Kingdom	Bath, Canterbury, Edinburgh, London, Wilton	
Subtotal	16	33
Asia	China	Guilin, Shanghai
	Hong Kong	Hong Kong
	India	Chennai (Madras), Delhi/New Delhi, Mumbai (Bombay)
	Iran	Tehran, Elburz Mountains
	Israel	Haifa, Jerusalem, Tel Aviv
	Japan	Tokyo
	Macao	Macao
	Malaysia	Kuala Lumpur
	Philippines	Manila
	Singapore	Singapore
	Sri Lanka	Colombo
	Thailand	Bangkok
	Vietnam	Ho Chi Minh City
Subtotal	13	19
Latin America	Costa Rica	Heredia, Puntarenas, San Jose
	Mexico	Juarez
	Panama	Panama City
	Peru	Lima, Andes Mountain village
	Virgin Islands	St. Croix
Subtotal	5	8
Africa	Egypt	Cairo, Luxor
	Tunisia	Tunis
Subtotal	2	3
Australia, NZ	Australia	Sydney
	New Zealand	Auckland, Wellington
	Yap	village
Subtotal	3	4
North America	Canada	Edmonton
	United States	Baltimore, Philadelphia
Subtotal	2	3
Total	41	70

Table 10. Windows as a proportion of front walls (grouped by construction and function type).

Windows as a Proportion of Front Walls UTBT and World Set Aggregated by Groups (Construction and Function Type)						
Group	Mass Construction			Framed Construction		
	No. of Examples	Percent Range	Mean Percent	No. of Examples	Percent Range	Mean Percent
Houses	39	3.9–22.3	11.1	7	7.8–13.1	10.7
Apartments	17	10.4–34.3	17.6	13	9.9–39.4	21.0
Hotels	6	12.4–37.3	16.9	20	12.1–38.0	22.6
Offices	10	9.9–20.5	15.0	19	11.3–58.8	34.3
Industrial/storage	7	5.6–27.4	18.1	9	1.3–7.2	3.9
Large masonry buildings	13	5.1–24.4	8.5	—	—	—
All buildings	92	3.9–37.3	13.4	68	1.3–58.8	21.3

Note: UTBT = urban terrain building type.

Table 11. Windows and doors as a proportion of front walls (grouped by construction and function type).

Windows and Doors as a Proportion of Front Walls UTBT and World Set Aggregated by Groups (Construction and Function Type)						
Group	Mass Construction			Framed Construction		
	Percent Windows	Percent Doors	Percent Windows and Doors	Percent Windows	Percent Doors	Percent Windows and Doors
Houses	11.1	4.7	15.5	10.7	4.5	15.5
Apartments	17.6	5.4	19.9	21.0	4.0	20.6
Hotels	16.9	3.5	23.2	22.6	2.2	23.3
Offices	15.0	3.0	18.6	34.3	2.1	34.3
Industrial/storage	18.1	5.7	14.3	3.9	19.8	16.8
Large masonry buildings	8.5	3.3	10.8	—	—	—
Mean percent	13.4	4.4	16.7	21.3	4.2	25.3

Note: UTBT = urban terrain building type.

9.1.5 Data Analysis

The data in table 10 are grouped by construction type and function.

The functional types listed (houses, apartments, hotels, offices, industrial/storage, and large stone buildings [mass only]) are universal. The data show relationships between function and construction type.

All percentages are mean, not median, and are broadly representative. Data are not just a mean of the percentages. For example, the figure 11.1% for mass construction houses is the mean for all 39 house examples.

The mean percentages that windows form of houses' front walls are almost identical in both mass and framed construction houses (11.1% mass vs. 10.7% framed). Common house architecture and style are more important than the construction method. The universal practice of providing windows to each room is evident. In addition, window size is a near constant for rooms of

various functions (covered in table 14). Bedroom windows are small for privacy and to limit light. By design, kitchen windows are also fairly small. Bathroom windows are even smaller. The largest windows are in the daytime living areas, the living room, the great room, etc. The opportunity to have large windows with framed buildings and their non-load-bearing walls is not taken.

The same principles apply to some degree for apartments, but the percentage differences (17.6% mass vs. 21.0% framed) are accounted for by the fact that framed apartment buildings are often modern-design high-rise structures with large windows enhancing the total appearance of the building. And, especially in upper floors, there is less concern for privacy than in a low-rise building where “view” apartments are desired (and always command the highest rent). The window figure for mass apartments (17.6%) is higher than that for houses (11.1%) thanks mainly to the practice of having glass occupy nearly all of the outer wall of a “box” in box-wall construction.

The figures for hotels (16.9% mass vs. 22.6% framed) show a similar pattern. Not only are large windows seen as desirable, but individual hotel rooms in modern framed construction hotels are larger than those found in older mass buildings. (Small room size has posed a special problem in bringing old hotels up to modern standards.)

Differences between the two forms of construction show markedly when comparing window percentages for offices (15.0% mass vs. 34.3% framed). Part of this difference is that abundant light was always desired in old masonry buildings, but the structure limitations would not allow it. Another reason is the sea change that has occurred in the design and use of offices. Prior to about 1950, office buildings were designed for a market of individual professionals renting single offices. In modern times, with large corporations as major players, offices are designed to have large, open bays with space divided (if at all) with low partitions, i.e., “cubicles.”

The reverse is seen with industrial/storage buildings (18.1% mass vs. 3.9% framed). The older buildings (mass) supported functions, such as a textile factory, that needed as much natural light as possible, especially in the early days of electricity. (Largely abandoned factory buildings in New England are good examples.) Modern framed structures, especially large-volume buildings, rely on artificial light, and, in many instances, require a controlled environment.

The entry for large masonry buildings can, by definition, mean only mass construction buildings. Here, the small figure of 8.5% reflects in part the unwillingness to devote much space to integrity-robbing windows and in part to window technology before large plates of glass were viable. The use of small pieces of stained glass in churches is a good example.

The aggregate totals of 13.4% for mass structures vs. 21.3% for framed is telling.

The data in table 11 are grouped by construction and function type. The proportion of wall space devoted to doors is essentially very small, ranging from 2.1% to 5.7% for all structures, excluding framed industrial/storage that has large openings to allow truck entrance. Architects

keep door size to a minimum for security reasons. Doors must be lockable and generally entry-proof. Guards are posted in critical instances.

One reason for differences between morphological/functional building types is simply building height. Low buildings have a higher proportion of doors to walls than do tall buildings. A good example are the figures for houses vs. a tall (framed) office building. The proportion of doors in houses is 4.7% for mass and 4.5% for framed construction, while the framed office class has a door proportion of only 2.1%. Mass construction hotels have 3.5%, but framed hotels, owing to their greater number of floors, typically have only 2.2%. Aggregate figures for all functions are only 4.4% for mass and 4.2% for framed buildings.

The figures for doors and windows combined contributes little to the figures for the proportions of windows (as seen in table 10) due to the relatively low figures for doors.

9.1.6 Discrete Construction Type Buildings by Function

Window-to-wall proportions for specific construction/function forms (table 12 for mass construction and table 13 for framed construction) vary somewhat from the aggregations reported in the previous two tables.

Table 12. Mass construction buildings.

Windows as a Proportion of Front Walls World Set by Specific Mass Construction Building Types			
Specific Buildings	Mass Construction		
	No. of Examples	Percent Range	Mean Percent
Houses			
Stone houses	6	4.6–12.5	7.8
Adobe house	1	—	6.5
Brick houses	12	5.3–22.3	13.9
Brick row houses	6	5.4–16.5	12.1
CMU house	6	3.9–15.3	10.1
Apartments			
Brick apartments	9	10.4–16.9	13.1
Box-wall apartments	6	13.7–34.3	24.2
Hotels			
Brick hotels	5	12.4–22.1	16.9
Offices			
Brick offices	9	9.9–20.5	15.0
Industrial/Storage Buildings			
Brick	5	6.4–27.4	18.1
Large masonry buildings	12	1.6–19.1	8.5
Total Number of Buildings: 77			

Note: CMU = concrete masonry unit.

Table 13. Framed construction buildings.

Windows as a Proportion of Front Walls World Set by Specific Framed Construction Building Types			
Specific Buildings	Framed Construction		
	No. of Examples	Percent Range	Mean Percent
Houses			
Wood framed	4	7.8–11.2	9.1
Apartments			
Light-clad curtain wall	6	13.3–39.4	27.2
Light-clad infill wall	6	9.3–21.3	15.7
Hotels			
Heavy clad	9	12.1–30.9	18.3
Light-clad curtain wall	6	10.7–44.2	21.8
Light-clad infill wall	3	15.9–35.3	28.1
Offices			
Light-clad curtain wall	9	16.3–58.8	41.1
Light-clad infill wall	6	11.3–34.9	22.6
Industrial/Storage Buildings			
Light clad	6	2.1–7.2	4.4
Total Number of Buildings: 55			

For mass-constructed houses (table 12), stone houses (7.8%) and adobe houses (6.5%) have very low window-to-wall percentages. While the form of construction would allow for more and larger windows, other restrictions emerge. Many of these structures are found in poor areas where providing windows represents an unacceptable construction expense. Security is also a factor (a good example are the small windows seen in American frontier log cabins). Another factor is a requirement for as much insulation as possible in desert climates. Finally, in the case of adobe dwellings in Muslim countries, privacy needs are paramount; lighting and ventilation in these cases normally come from a central courtyard and not from windows facing the outer world.

Brick houses, on the other hand, with their higher average window-to-wall percentages (13.9%), are located in the modern Western world and in higher latitudes where lighting needs dominate. Average figures for window percentages here are in the neighborhood of twice those of stone and adobe houses. Figures for row houses (12.1%) and CMU houses (10.1%) show nearly the same differences.

The apartment class has two very different forms of construction, even though they both fall under the rubric of mass. The brick apartments (13.1% window) use unit masonry construction while the box-wall buildings (24.2% window) are made of poured concrete slabs. Brick walls have the usual restriction that wall integrity cannot be compromised while box-wall cells have one open end devoted almost entirely to a window.

The figures for brick hotels, brick offices, brick industrial/storage buildings, and large masonry buildings are repeated from table 11.

The opportunities afforded through the use of frame construction to provide windows larger than those associated with mass construction are clear with only houses having small proportions (just 9.1% for wood-framed houses and industrial/storage buildings with 4.4%, contrasted with double-digit figures for the other building types). Again, style and human scale dominate.

Table 13 makes a distinction between windows that are a part of cladding of a framed structure as opposed to situations where a window forms part of an infill wall. Cladding is applied on the outside of a building's frame while infill walls or windows fill the space between columns and beams.

For apartment buildings, curtain walls have a higher proportion of windows than do those with infill walls (27.2% vs. 15.7% for infill walls). For the hotels measured, however, the infill walls have a somewhat higher proportion of windows (28.1% to 21.8%). These numbers are appreciably higher than the window proportion of heavy-clad hotels (18.3%). For offices, as would also be expected, curtain walls have a higher percentage of glass (41.6%) than do infill walls (22.6%).

9.1.7 Window Dimensions

Several factors affect window size. Building morphology, i.e., mass vs. framed, provides one set of parameters, and building function forms the other.

As noted earlier, buildings of mass construction have the limitation that reduced wall integrity restricts the number and size of windows—framed structures have no such limitation. A curtain wall of a framed building can be all glass, although in practice, opaque glass usually masks floor ends and structural members.

Table 14 reveals significant differences in window size for some building construction types and functions, and very little for others. Little difference is seen for houses whether they are mass or framed (1.2 m² for the former, 1.9 m² for the latter). Looking at the range of sizes, the size of windows in a house is in direct response to the need and desirability for lighting and ventilation for the various room functions. Daytime occupancy rooms favor larger windows than do sleeping rooms, kitchens, or bathrooms.

The same reasoning applies to apartments, although box-wall apartments will often have large windows at the exposed end of the box, contributing to the aggregate figure for mass apartments (2.4 m²), while framed apartments are similar at 2.7 m².

With hotels, the range is also fairly close (1.9 m² for mass to 2.4 m² for framed). That the differences are as close as they are reflects the small windows of masonry-styled, heavy-clad framed buildings, even though windows physically could have been designed larger. Also, windows in some modern framed buildings are kept intentionally small where a factor, such as heat preservation in cool climate areas, is a consideration.

Table 14. Mean window size in square meters (grouped by construction and function type).

Mean Window Size in Square Meters by Groups (Construction and Function Type)						
Group	Mass Construction			Framed Construction		
	No. of Examples	Range (m)	Mean (m ²)	No. of Examples	Range (m)	Mean (m ²)
Houses	21	0.5 × 0.5 to 1 × 2	1.2	9	1 × 1 to 2 × 2	1.9
Apartments	8	0.75 × 1.5 to 1.5 × 3	2.4	17	1 × 1 to 1.5 × 3	2.7
Hotels	5	1 × 1.5 to 1.5 × 2	1.9	24	1 × 1 to 1.5 × 3.5	2.4
Offices	10	1 × 1.5 to 1.5 × 2	2.1	16	1 × 2 to 1.5 × 40	26.7
Industrial/storage	5	1 × 2.5 to 2 × 2.5	3.8	7	1 × 1 to 1.5 × 5	2.5
Large masonry buildings	11	0.7 × 1 to 2 × 2	2.2	—	—	—
All buildings	60	0.5 × 0.5 to 2 × 2.5	1.9	73	0.5 × 1 to 1.5 × 40	7.8

The greatest difference in window size is seen with mass construction vs. framed construction offices. Windows of the former average but 2.1 m², while the aggregate for framed buildings is 26.7 m². Many of the glistening high-rise office buildings in major cities throughout the world will have very high proportions of glass, around 50% and more (see photo examples in the appendix).

Window sizes for industrial/storage buildings reverse the previous situation in that the mass construction buildings have larger windows than do modern framed structures because building users were seeking natural illumination for the manufacturing processes conducted within. In addition, buildings were smaller and especially narrower, thus allowing greater natural light to penetrate interiors. Windows on walls of modern industrial/storage buildings would be of little use.

Windows in large masonry structures are traditionally very small (at 2.2%). Some of this is a function of style, e.g., the long, narrow windows of Gothic-style European cathedrals.

9.1.8 Window Thickness

The thickness of window glass, thus the strength, is a function of overall window dimensions. Small-area windows are thin, and big windows must be thicker and stronger. House windows are about 2 mm thick, apartment windows range from 2 to 4 mm, and hotel windows range from 3 to 6 mm. The office windows of high-rise structures range from 6 to 9 mm, where resistance to high winds is a factor. Several forms of protection have been devised.

9.1.9 Window Patterns

The arrangement of a building's windows produces certain replicating patterns. These result in part from the form of construction (mass or framed) and in part from the functions the building serves. For some functions, an architect has several choices. For instance, a modern-framed high-rise office building might have windows placed in long horizontal rows (the spandrel pattern, figure 7), or windows may simply be infills among columns and beams (figure 8). Alternatively, the windows may be bounded by vertical mullions (figure 9) or placed on the outside of the frame members as curtain walls (figure 10).



Figure 7. A framed, light-clad office building with a spandrel window pattern. Glass, both clear and opaque, lies between vertical mullions.

In other functions, such as a framed, heavy-clad, or brick masonry hotel, the structure must provide a window for each guest room, resulting in an easily recognizable pattern. In the case of brick masonry construction, the windows must be aligned vertically so as to maximize wall integrity. Framed, heavy-clad buildings followed masonry style. Relating windows to room function is seen with houses. Observed from outside, window size and placement provide ready clues to the floor plan of a house.

While great variety within window pattern types is found, the following figures will serve to define the general types of patterns.



Figure 8. Windows set in between column and beam members in a framed office building form an infill pattern.



Figure 9. An example of a curtain wall being placed on a R/C-framed office building. Glass, clear and opaque, is being placed between narrow spandrels and mullions.



Figure 10. Clear and opaque glass form a curtain wall being installed on a framed office building.

9.2 Roofs

A building's roof—a component of its elevation, its configuration, and its composition—is of key interest to the urban operations community. This report provides geographic distribution of various roofing materials in theaters throughout the world, the morphological and functional types and characteristics of buildings involved, the physical characteristics of the roofing materials themselves, and the shapes of the target roofs. An unanticipated benefit from a focus on roofs is the development of principles involving the nature of building construction, the relationships to climate, the tie to a region's customs, and the presence of various roof types to the level and history of economic development, especially in developing nations.

9.2.1 Method

Examples of the physical shapes of roofs come from a spectrum of cities in various world regions, i.e., Europe, the Middle East, Northeast Asia, Latin America, and Tropical Africa. Cities selected for observation within these regions are listed in table 15.

Visual images came from various sources. For Bremen, a book of aerial oblique photos was most useful, especially when combined with ground truth photographs. For Uppsala, local knowledge plus aerial photo coverage in both oblique and vertical form (supplied by the Swedish government) were used. Cairo was covered by oblique air photographs and supplemented with a Digital Globe satellite image. Ground truth photographs in Tel Aviv were supported with a book of oblique air photos. An enhanced satellite image of Al Fallujah provided the required information. An Ikonos satellite image of Kuwait City gave ample information. An Ikonos

image of Shanghai was also used, supplemented with ground truth photos and oblique photographs posted on the Web. For both Seoul and Pyongyang, a combination of satellite views and oblique and ground photos from the Web were employed. For Panama City, an Ikonos image supported ground truth photos. For San Jose, Costa Rica, a combination of vertical air photographs, low-altitude oblique air photographs taken by Ellefsen, and ground truth photos were used. Finally, for Lagos, an Ikonos image was supported by a Digital Globe image and ground photos from the Web.

A standard procedure was followed in interpreting the information from the images used.

9.2.2 Analysis of Roof Shape

Conclusions can be drawn from examining the data in table 15, which is divided into (1) similarities and differences by class of function, i.e., houses, apartment buildings, offices, commercial buildings, industrial/storage buildings, and institutional buildings, and (2) relationships to regional characteristics, especially the climatic factors of wetness and aridity.

Table 15 focuses on a basic distinction in roof morphology, flat vs. pitched roofs. Considering that all roof forms must have enough slope for water to drain, the term “flat” is used to describe roofs that appear flat to the casual observer. The minimum pitch for a flat roof to have drainage is 20 mm in 1 m. Figure 11 shows a typical flat roof.

Table 15. Roof shapes in selected world cities.

Roof Shape: Selected World Cities Percentage Pitched Roof						
Function/Land Use						
Region/City	Houses (%)	Apartment Buildings (%)	Offices (%)	Commercial (%)	Industrial /Storage (%)	Institutional (%)
Europe						
Bremen	90–100	20–30	30–40	60–70	20–30	90–100
Uppsala	100	80–90	90–100	50–60	80–90	100
Middle East						
Cairo	0	0	0	0	20–30	0
Tel Aviv	80–100	10–20	0	0	70–80	60–70
Al Fallujah	0	0	0	0	30–40	0
Kuwait City	0	0	0	0	80–90	10–20
Northeast Asia						
Shanghai	100	10–20	10–20	10–20	90–100	20–30
Seoul	100	10–20	10–20	0–10	80–90	80–90
Pyongyang	100	20–30	10–20	0–10	80–90	80–90
Latin America						
Panama City	100	10–20	10–20	90–100	90–100	80–90
San Jose	90–100	20–30	10–20	20–30	90–100	90–100
Tropical Africa						
Lagos	100	0	0	0	90–100	90–100



Figure 11. Typical “flat” roof with air conditioning and ventilation units.
Note tar paper strips, parapet, and slight slope to gable roof.

Pitched roofs vary in steepness from around 45° to 20° . In the building trades, roof pitch is a term used to express the ratio of a roof’s vertical rise in inches (in the United States) to each foot of run—the horizontal distance. A 3-in-12 pitch describes a roof that rises 3 in vertically for every 12 in of horizontal distance.

Pitched roofs also have a distinctive morphology. See figure 12 for the five basic shapes.

The use of flat or pitched (and degree of pitch) varies in accordance with the following:

1. Climate and the need to protect a structure from heavy and frequent rainfall, or, in some cases, to support heavy snow loads.
2. Availability of local materials for both roof structure and surfacing materials, and access to modern building materials, e.g., steel rebar for constructing reinforced concrete roofs on R/C buildings.
3. Relationship to construction type. For example, R/C roofs are practical for high-rise frame or box wall construction where preparing a roof is simply a repeat of constructing another floor, with the exception that the roof surface must have some protective material.
4. Tradition and style. To be aesthetically pleasing and to match a traditional look associated with a region, pitched roofs are sometimes seen on a framed construction high-rise building.

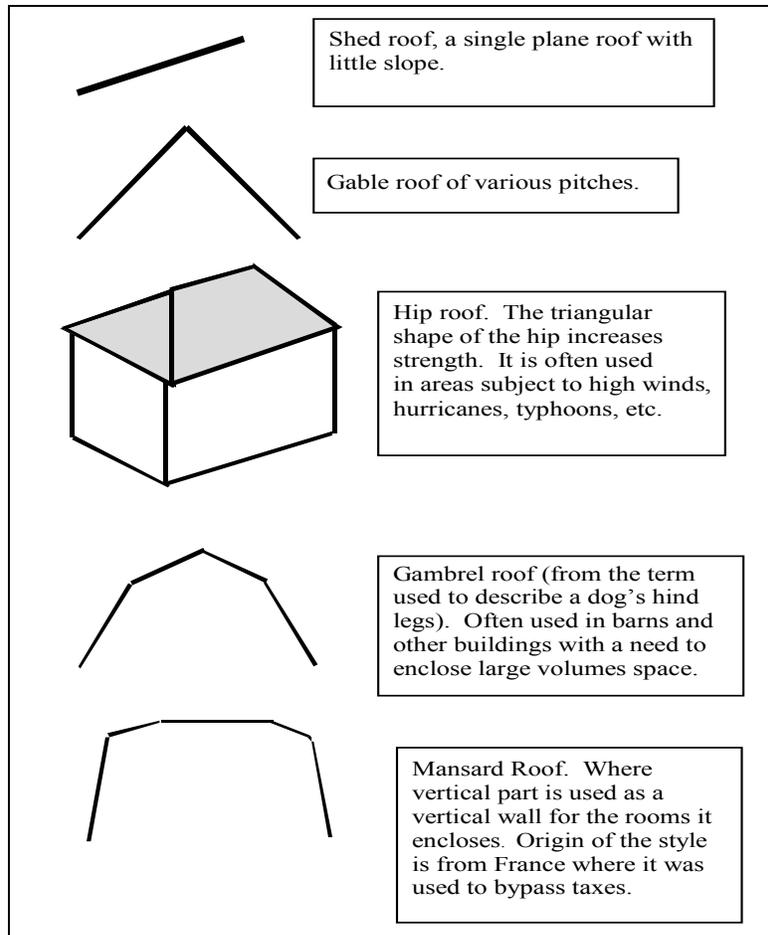


Figure 12. Five basic roof shapes.

9.2.3 Analysis of Building Function

9.2.3.1 Houses. Looking first at houses (refer to table 15), we see manifestations of the previous four principles. Pitched roofs dominate in the two European sample cities, Bremen and Uppsala, with 90% to 100% for the former and 100% for the latter. Response to a damp marine West Coast climate is one response, but historical tradition, tracing its roots to steeply pitched thatch roofs, is also followed (see figure 13).

Houses in the Middle Eastern cities of Cairo, Al Fallujah, and Kuwait City have mainly flat roofs that are not only a response to the dry climates in which they're found, but also to the lack of wood for rafters. In some Middle Eastern cities (such as Baghdad), the flat roofs may have a wall running along the edge of the building (perimeter parapet). The flat roofs of houses in dry climates are well demonstrated by figure 14 of Kano, Nigeria (located in the dry climate area of the northern part of the country). Tel Aviv is the exception, where for free-standing houses (probably because of the European origin of most of the country's citizens) the preferred roof type is pitched. Most are made with semicircular red terra cotta tile.



Figure 13. European row houses with terra cotta tile pitched roofs.

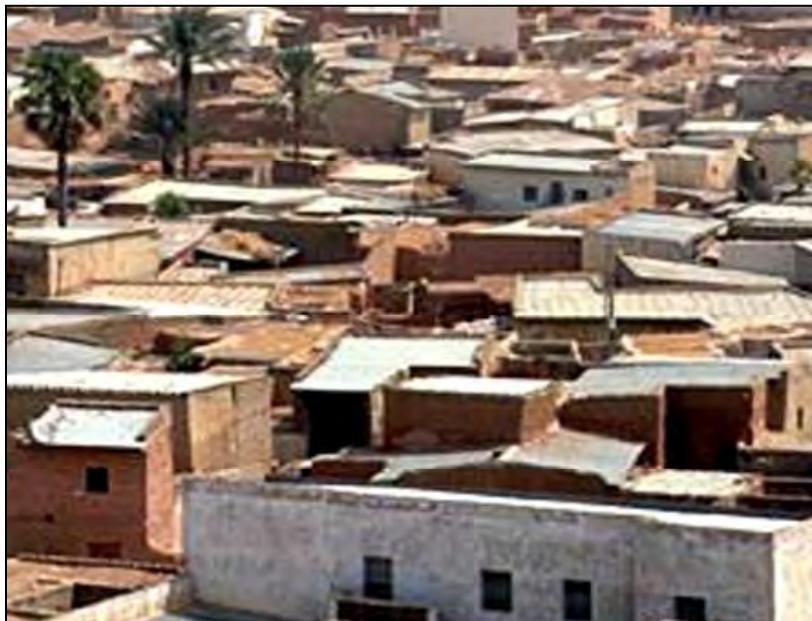


Figure 14. Mostly flat roofs on masonry structures in Africa.

Northern European institutional structures have historically pitched roofs (see figure 15). For the Northeast Asian cities examined—Shanghai, Seoul, and Pyongyang—house roofs are all pitched, accounted for by the generally moist summer climate, the snow in North Korea, and the tradition of pitched roofs in temple buildings where roof shape has spiritual origins. Figure 16 illustrates the point.



Figure 15. Northern European administrative/cultural building with pitched roof.

The Latin American representative cities, Panama City and San Jose, also have predominantly pitched roofs. Panama City, with its tropical rainforest climate (rainfall throughout the year), has a special need for sloping roofs. A few flat roofs are seen in San Jose with its only seasonally wet climate.

Finally, Lagos, also located in a tropical rainforest climate close to the Equator, has a practical need for sloping roofs.

9.2.3.2 Apartment Buildings. The apartment class used here broadly comprises both low-rise buildings (3 to 5 stories) and very tall buildings (50 stories). Both the form of construction (often R/C framed with the taller buildings) and tradition come into play to explain the variances in the proportion of pitched roofs in the different regions. For the European cities, Bremen has a high proportion of flat roofs, especially in the extensive post–World War II developments at the edge of the city. Apartment buildings near the city’s center follow the regional tradition for houses and have pitched terra cotta tile roofs. Uppsala shows this characteristic to an even greater degree with its pitched roof apartments reaching 80% to 90% of all apartment roofs.

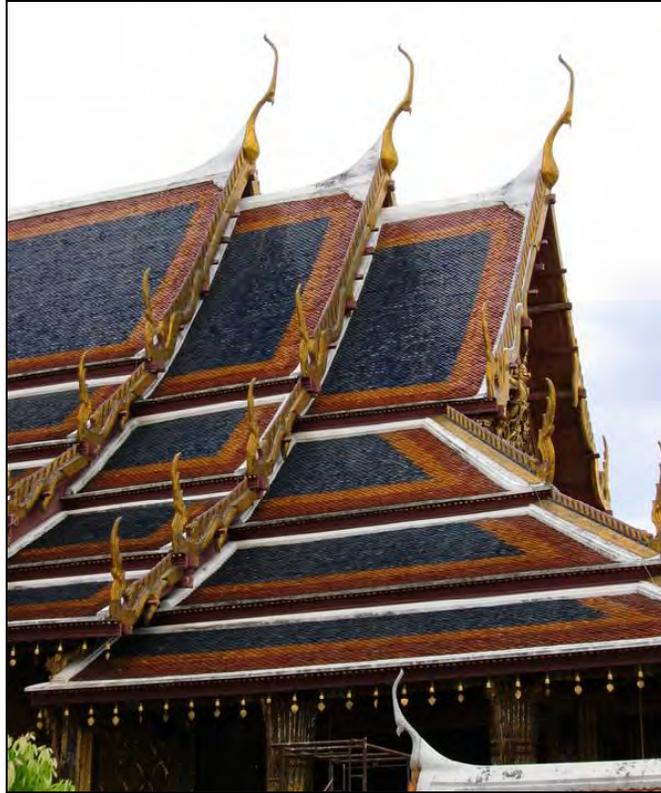


Figure 16. Temple building in Thailand with typical pitched roof.

The same three Middle Eastern cities that have flat-roofed houses also have all flat-roofed apartment buildings. In Tel Aviv, however, thanks to a European-based population tradition, some 10% to 20% of apartment buildings have pitched roofs.

In the Northeast Asian cities, the pitched roof tradition is observed somewhat in Shanghai and Seoul apartment buildings. Their great number of modern R/C-framed high-rise apartment buildings shows the fewest pitched roofs. Tall, flat-roofed apartment buildings also dominate in Seoul and Pyongyang (see figure 17), although a few pitched roof buildings occur.

A small proportion of apartment buildings in the Latin American cities group has pitched roofs (10% to 30%).

In Lagos, even though the tradition of houses is universally pitched, the modern apartment buildings all have flat roofs.



Figure 17. Flat-roofed high-rise apartment buildings in Northeast Asia.

9.2.3.3 Office Buildings. One would expect tall, framed office buildings to have flat roofs. This is essentially true, although some buildings have such roof structures as elevator housings and air-conditioning-equipment protective shelters; some also have reinforced helicopter-landing platforms. Exceptions on the list (table 15) are the European cities Bremen and Uppsala where tradition reigns and climate must be considered. Interestingly, Beijing and other Chinese cities have some office buildings with decorative pitched roofs (see figure 18).



Figure 18. Stylized pitched roofs on Asian office buildings.

9.2.3.4 Commercial Buildings. These structures are mainly lower-rise and are found in central parts of cities and along major commercial streets. Being lower than the high-rise office buildings, many have pitched roofs following the tradition of houses and some apartment buildings. Roughly half of the commercial buildings in Bremen and Uppsala have pitched roofs. A few (0% to 20%) are seen in the Northeast Asian cities. For the Latin American cities, 90% to 100% of Panama City's structures have pitched roofs because of concern with its often heavy rainfall. San Jose, with less of a rain problem, has some 20% to 30% pitched roofs.

9.2.3.5 Industrial/Storage Buildings. Of all the building types in the table, industrial/storage buildings, with only two minor exceptions, predominantly have pitched roofs, regardless of location. The reason is straightforward. Most of these buildings—used either for the manufacturing process, storage, or a combination—require a large volume of interior enclosed space, are not internally subdivided into rooms of various sizes, and do not require air conditioning. Pitched roofs, usually supported by trusses, are common. See figures 19 and 20.



Figure 19. Most of the industrial/storage buildings in this complex have metal pitched roofs.



Figure 20. Metal-roofed industrial storage buildings in South America.

In the Middle East, where a great majority of buildings have flat roofs, high percentages of the industrial/storage structures have pitched roofs. Cairo has 20% to 30%, Tel Aviv has 70% to 80%, Al Fallujah has 30% to 40%, and Kuwait City has 80% to 90%. A common occurrence in an industrial complex is to see a flat-roofed structure housing the administrative offices (almost always air conditioned) while adjacent industrial/storage buildings have pitched roofs. A similar situation is seen in the Latin American cities of Panama City and San Jose, and in the African city of Lagos.

9.2.3.6 Institutional Buildings. Institutional structures, such as governmental, religious, or academic, have traditionally elected to use pitched roofs over flat for architectural and spiritual reasons. Bremen and Uppsala both have classic-styled governmental structures. The Middle East has numerous such structures (see figure 21). In Cairo, Al Fallujah, and Kuwait City, where most other buildings have flat roofs, mosques, museums, and the like have non-flat roofs. Tradition comes into play in Northeast Asia where temples and other monumental buildings have classic, decorative pitched roofs (see figure 16). Panama City, San Jose, and Lagos show the same favoring of traditional pitched roofs.



Figure 21. Terra cotta pitched roofs on academic buildings in the Middle East.

9.2.4 Worldwide Roof Constants

Although aberrations are inevitable when looking at building and roofing practices for cities around the world, certain constants can be identified.

1. Houses in rainy areas have pitched roofs, and those in arid areas have flat roofs.
2. High-rise office buildings, hotels, etc., commonly are light-clad framed structures or box-wall principle structures and, accordingly, have flat roofs, unless some cultural factor governs architecture.
3. Commercial buildings (stores for goods and services), especially along major streets or roads, have flat roofs.
4. Industrial/storage buildings will mainly have pitched roofs.
5. Institutional buildings will also mainly have pitched roofs.
6. Modern high-rise, framed construction buildings have been erected in great numbers in the developing world in recent decades, and most have flat roofs made with concrete.
7. Corrugated (and shaped) metal (steel, aluminum) is in wide use throughout the world for industrial/storage buildings. These buildings normally have pitched roofs. They are

especially common in wet tropical areas. The material is also frequently used in shanty towns (see figure 22).

8. Corrugated and shaped composite roof sheets are also widely used.

9.2.5 Roof Material Types

9.2.5.1 Concrete. Concrete is commonly used for flat roofs and especially for R/C-framed or box-wall buildings where the roof is simply another floor with weather proofing added. Foamed light-weight concrete can take the form of shakes or planks and can be used for pitched roofs when the underlying roof structure is made sufficiently strong. With flat roofs, factory-made lightweight foamed concrete planks are often used and placed upon a supporting structure. Or, a layer of concrete may be poured on top of a corrugated steel base, reinforced with a steel mesh layer. A layer of felt is usually laid on top of the concrete with a layer of bitumen (asphalt and coal tar pitch) atop that. A thin layer of gravel (10 to 13 mm) is placed atop the bitumen to protect the felt and the bitumen. Figure 23 is an example.



Figure 22. Corrugated steel roofs on shanties in Asia.

9.2.5.2 Terra Cotta. Tiles of this material have been used since early times, taking a flat form, a concave, or a convex form and laid on a pitched roof in an overlay pattern (with the covered part thinner than the uncovered part); thickness varies from 10 to 20 mm. A mix of flat and convex tiles is seen in the photo of rooftops in southern Europe (figure 24). Ribbed tiles are seen on the hip-roofed house in South Asia (figure 25).

9.2.5.3 Wood. Sawn shingles and split shakes are commonly used where wood is plentiful or can be imported at low cost.



Figure 23. Concrete flat roofs on buildings in the Middle East.



Figure 24. Terra cotta-tiled roof in southern Europe. Detailed photo shows a common practice of convex tile placed over flat tiles.

9.2.5.4 Metal. Steel and aluminum are used widely for roofing and fabricated into a great variety of shapes, from simple corrugation to many forms of ribbing. Thickness is only 1 to 3 mm. A typical developing nation shanty in Asia shows ribbed galvanized sheet-metal steel in various stages of rust (figure 22). Figure 26 shows a ribbed steel-pitched roof on the middle house (terra cotta tile on the left house and rolled asphalt material on the flat roof on the right). Corrugated steel is classed by the distance between the ridges; a common figure is a ridge to ridge distance of 2 1/2 in with a 1/2-in-deep valley. Thickness is reported by gage.



Figure 25. Ribbed terra cotta tile hip-roof on a CMU construction in South Asia.



Figure 26. Ribbed steel roof (middle), tile roof (left), and rolled roofing (right) in northern Europe.

9.2.5.5 Composite. Various fibers are combined with resins to form an effective roof material; coir (from coconuts) and jute are used in India. Asbestos has been employed widely. Thickness is usually greater than with metal, ranging from 4 to 8 mm. Sheets are often made of a combination of asbestos fiber and Portland cement. The product is light gray in color and, as it doesn't require paint, it is readily identified in the field. Lightweight steel-framed industrial/storage buildings will frequently use this material.

9.2.5.6 Brick and Stone. Brick and stone are used in dome and vault forms to enclose space. They are also widely used in mosques and houses in arid Middle Eastern areas. Low brick arches are used in conjunction with joists to form flat roofs; a veneer of concrete is put on top.

9.2.5.7 Wattle. Integrated with mud, this material is seen on many adobe houses in the Middle East.

9.2.5.8 Thatch. A traditional roof material in Europe and elsewhere in rural areas, but not often seen today.

9.2.5.9 Pitched Roof Support. Pitched roofs are supported by rafters on which purlins are attached at right angles. Trusses may be required to support these.

10. Plate Group 3: Floor Plans/Room Dimensions

Floor plans are provided for each of the 44 building types. Planimetric plans are provided for each building type, and, in some instances, isometric drawings (at 45°) are included to enhance the visual perception of building interiors. For multiple floor buildings, the upper floor (in the case of a two-story building) is provided, and for buildings with more than two floors, a representative upper floor plan is given. Note that the terms ground floor and upper floors are employed to be compatible with international standards. The U.S. usage of the term "first floor" for the "ground floor" is not applied abroad where the term ground floor indicates exactly what that suggests, with the first floor above the ground floor being designated the first floor, and so on to the full height of the building.

Room dimensions are given in meters. Venting (windows and doors) is shown at scale, as are dimensions of both exterior and interior walls. An example of a single-story industrial/storage building is displayed in figure 27 (from plate framed 16-3-a in the catalog).

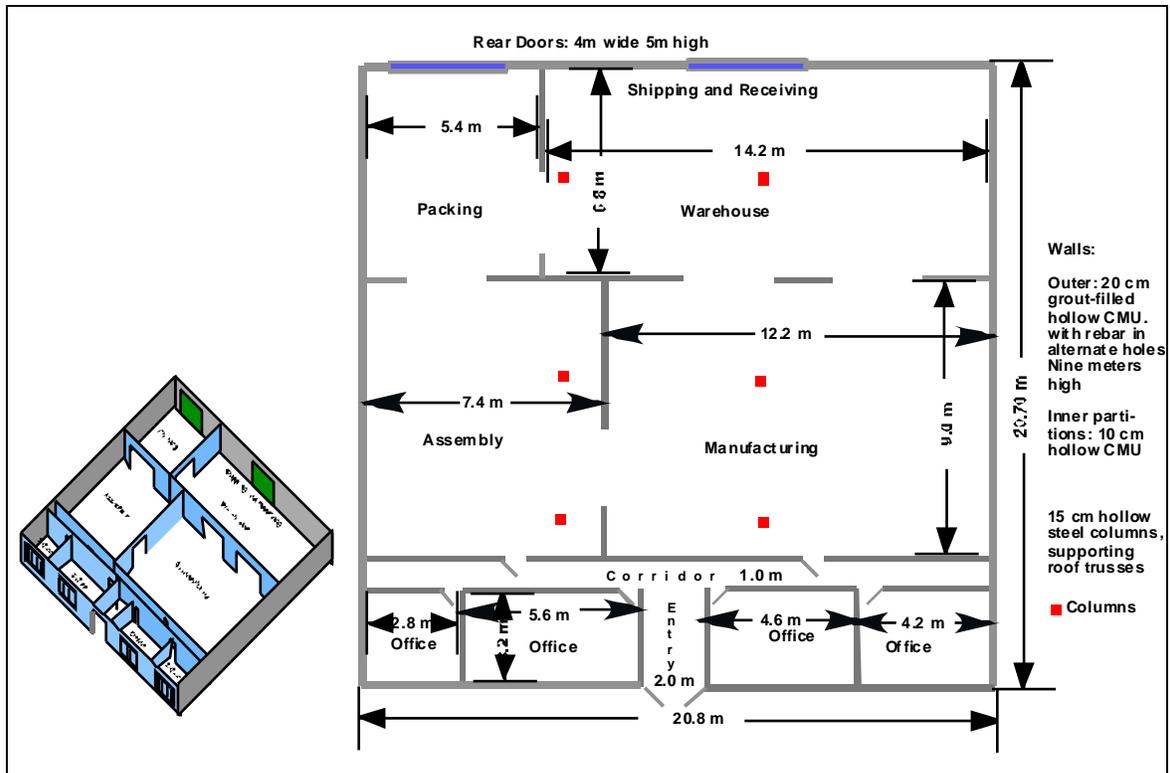


Figure 27. Planimetric floor plan and isometric rendering of an industrial/storage building.

Table 16 gives room dimensions by functional classes of the 44 building types (houses, apartments, row houses, hotels, offices, industrial/storage buildings, retail stores, and institutions). Specifics are given by type of room within these functions where applicable, e.g., living rooms, bedrooms, kitchens for houses and apartments/row houses.

Typical floor plan dimensions of length and width, extracted from the planimetric floor plans for each building type, were used to calculate the average room area (in square meters). The average room volume (in cubic meters) was calculated by multiplying the average room area by the room height.

The number of rooms is given by type, as are range, area, height, volume, and type of UTZ where found. The ranges in room sizes are narrow in residential cases but spreads are greater for rooms located in hotel public areas, corporate offices, industrial/storage spaces, retail stores, and institutions.

The room sizes recorded in table 16, although derived independently, are consistent with the room measurements provided in other independent works such as Harold R. Sleeper's *Building Planning Design Standards*.

Table 16. Room dimensions by function for worldwide buildings.

Room Dimensions: By Function for Worldwide Buildings						
Function	Number of Cases	Range (m)	Average Area (m²)	Height (m)	Average Volume (m³)	UTZs Where Found
House						
Living room	12	4 × 4/8 × 4	21.5	3	64.5	A3, Dc3, Do3
Bedroom	27	3 × 3/4 × 5	13.1	2.5	32.9	A3, Dc3, Do3
Kitchen	12	2 × 3/4 × 4	10.8	2.5	27.1	A3, Dc3, Do3
Apartments/Row Houses						
Living room	8	4 × 3/6 × 4	20.1	3	60.4	A2, Dc2, Do2
Bedroom	10	3 × 3/5 × 3	12.9	2.5	32.3	A2, Dc2, Do2
Kitchen	11	2 × 2/4 × 2	7.5	2.5	18.6	A2, Dc2, Do2
Hotels						
Guest rooms	6	6 × 4/4 × 3	17.8	3	53.5	A1, A2, Dc1
Public rooms	5	16 × 10/40 × 21	417.2	5–7	2639.2	A1, A2, Dc1
Offices						
Private	11	7 × 4/8 × 6	37.9	3	113.7	A1, A2, Dc1, Dc5
Pub/Corp.	8	8 × 8/30 × 20	242.3	4–6	1288.5	A1, A2, Dc1, Dc5
Industrial/Storage						
Functional spaces	10	7 × 5/40 × 25	428.0	6–8	3032.4	A4, Dc4, Do4
Retail Stores	3	10 × 6/36/30	406.7	3–6	2326.7	A1, A2, A5, Dc1
Institutional	4	7 × 12/16 × 12	125.0	4	500.0	Dc6, Do6

Note: UTZ = urban terrain zone.

As would be expected, rooms in houses (living rooms, bedrooms, and kitchens) are all slightly larger than those found in apartments and row houses.

In the main, house rooms in most parts of the world will be smaller than the U.S. average. Still, they cannot be smaller than the minimum required for particular functions, considering that the size of humans and furniture is virtually universal.

While dimensions for houses and apartments/row houses show relatively little variance, hotel guest rooms show even less, considering the dedicated use of the rooms and the requirement for hotel builders to attain maximum cost-benefit. Public rooms do, of course, vary with need and function of the hotel (a hotel providing only guest rooms vs. a large convention/business-type establishment). At any rate, volumes of public rooms in major hotels are large and on par with many industrial/storage buildings or retail stores.

For large public space use or corporate offices—associated with framed high-rises—room size and volume are often large. A not uncommon situation is to find a room the width of a prestressed concrete beam (some 10 m) and the length of a few of these beams, giving a total open area often exceeding 300 or 400 m² and broken only by cubicle partitions.

The figures for the industrial/storage buildings reflect only the sample structures in this volume and do not include truly large industrial structures, such as an automobile or aircraft assembly plant.

Retail stores also range from the small examples herein (seen in crowded parts of developing nation cities) to the largest “big box” stores.

The last entry, institutional, cannot include the largest (but relatively rare) enclosed spaces, as in a major church or sports arena, but is intended to be representative of those widely encountered average spaces, such as schools.

11. Plate Group 4: Construction Features

Construction features illustrated in this group of plates vary in accordance with the nature of the particular type of construction. For mass construction (table 17), emphasis is placed on the types and dimensions of the material—concrete, the masonry units of mud brick, kiln-dried brick, CMUs, and terra cotta. Brick bonding types are also shown. Details are provided on concrete panel walls as used in box-wall principle construction and tilt-ups.

Mass construction examples include (1) mud brick composition, dimensions, and how they’re made; (2) materials and methods used in roofs of simple adobe buildings; (3) method of laying triple brick walls using English bonding; (4) nature of ultra-thick brick walls as seen in multistory brick buildings; and (5) composition and dimensions of R/C box-wall principle buildings.

For framed construction (table 18), the emphasis is on the nature of the frame and either the wall cladding or infill. Framed construction examples include (1) details on joining components of post- and beam-wood construction; (2) the form and composition of heavy cladding on tall steel-framed buildings; (3) the nature of central pylon construction used for some high-rises; (4) variations in infill materials as used in R/C-framed buildings; and (5) nature of very light corrugated steel walls in industrial/storage buildings.

12. The Catalog of Urban Terrain Building Types

The catalog is designed to serve as a reference to users interested in buildings as target types and support to urban operations worldwide by providing information on typical structures and construction types found in each region. Tables 4 and 5 provide the summary view of basic forms of construction. Table 6 provides building properties, e.g., wall and material thicknesses,

for the 44 urban terrain building types in one location for easy reference. The catalog offers specific data on all of the 44 universal building types. This is achieved in the 122 plates covering 23 mass construction building types, and the 121 plates covering the 21 framed construction building types.

Table 17. Mass urban terrain building types.

Twenty-Three Urban Terrain Building Types			
Building Type	No. of Plates	Building Type Name	Building Material
Mass 1	5	Stone house	Stone
Mass 2	6	Stone institutional building	Stone
Mass 3	7	Adobe house	Sun-dried mud brick (adobe)
Mass 4	8	Adobe store	Sun-dried mud brick (adobe)
Mass 5	8	Triple brick house	Kiln-fired brick
Mass 6	8	Triple brick Middle Eastern house	Kiln-fired brick
Mass 7	8	Brick row house	Kiln-fired brick
Mass 8	6	Brick apartment building	Kiln-fired brick
Mass 9	5	Brick hotel	Kiln-fired brick
Mass 10	5	Brick office building	Kiln-fired brick
Mass 11	5	Brick store	Kiln-fired brick
Mass 12	5	Brick mosque	Kiln-fired brick
Mass 13	5	Brick industrial/storage building	Kiln-fired brick
Mass 14	6	CMU house	CMUs
Mass 15	5	CMU store	CMUs
Mass 16	6	CMU industrial/storage building	CMUs
Mass 17	5	Brick-over-block house	CMUs and brick
Mass 18	7	Brick-over-block house German house	Large CMUs and brick
Mass 19	6	Concrete with stone cover apartment building	Poured concrete and stone
Mass 20	5	Concrete stone	Poured concrete
Mass 21	6	Tilt-up industrial storage building	Poured concrete
Mass 22	11	Box wall principle apartment building	Concrete panels
Mass 23	5	Box wall principle hotel	Concrete panels
Total Plates: 143			

Note: CMU = concrete masonry unit.

Mass 1-1 Place on Building Construction Chart

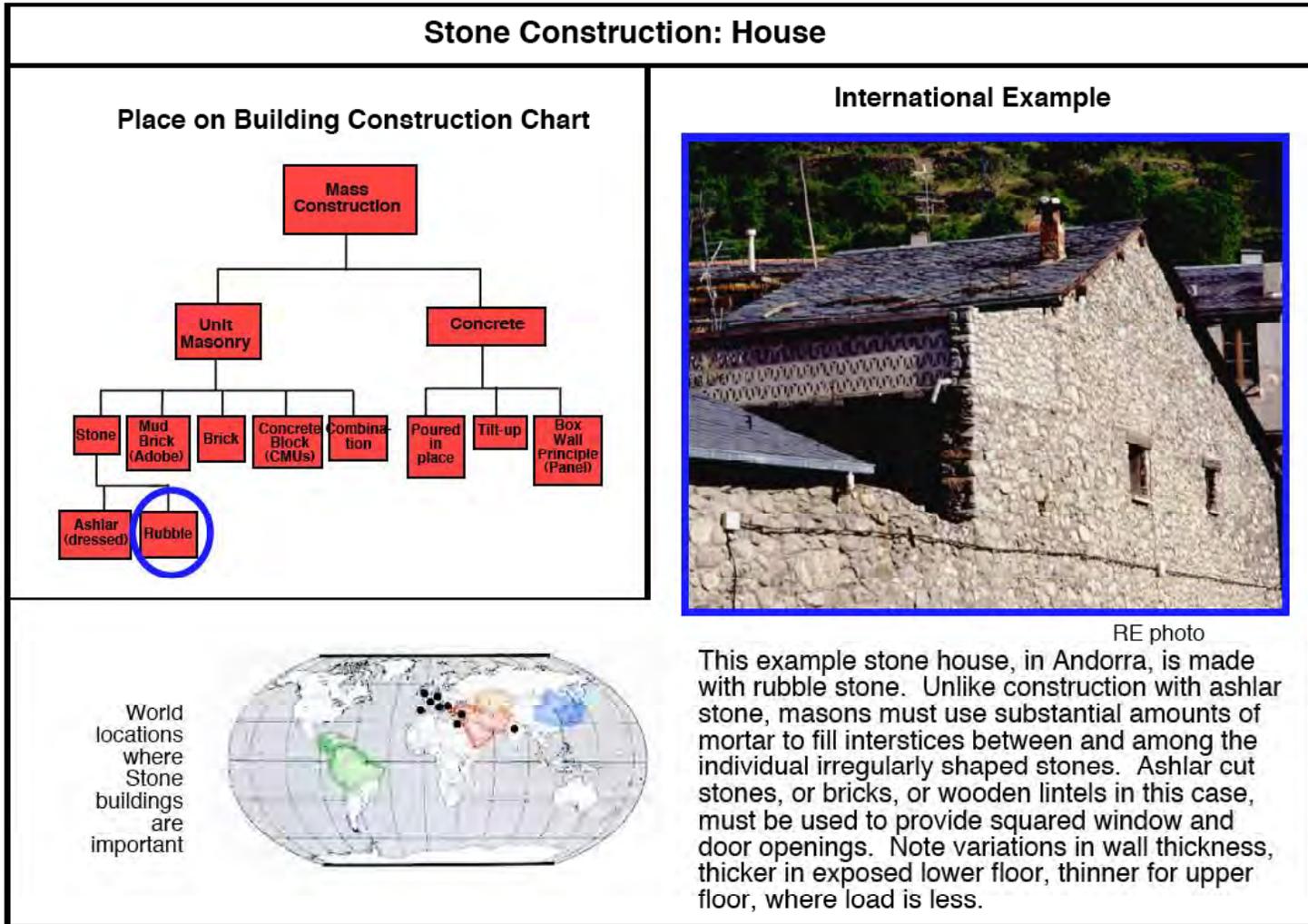


Figure 28. Mass 1-1 place on building construction chart.

Mass 1-2 Elevation

Stone Construction House

Commentary

This example, in a fortified hilltop village in Italy, shows a house with ashlar stone exposed on the two lower floors and rubble stone exposed on the top floor. Several modifications are suggested (by the presence of two entry doors) in this building that is at least 500 years old. Note: alignment of windows to preserve wall strength; and the tile pitched roof.

Terra cotta tile is used as a roofing material. The tiles lie on slats, at right angles, and the slats rest on rafters.



RE Photo 2004

Figure 29. Mass 1 elevation.

Mass 1-3-a Floor Plans

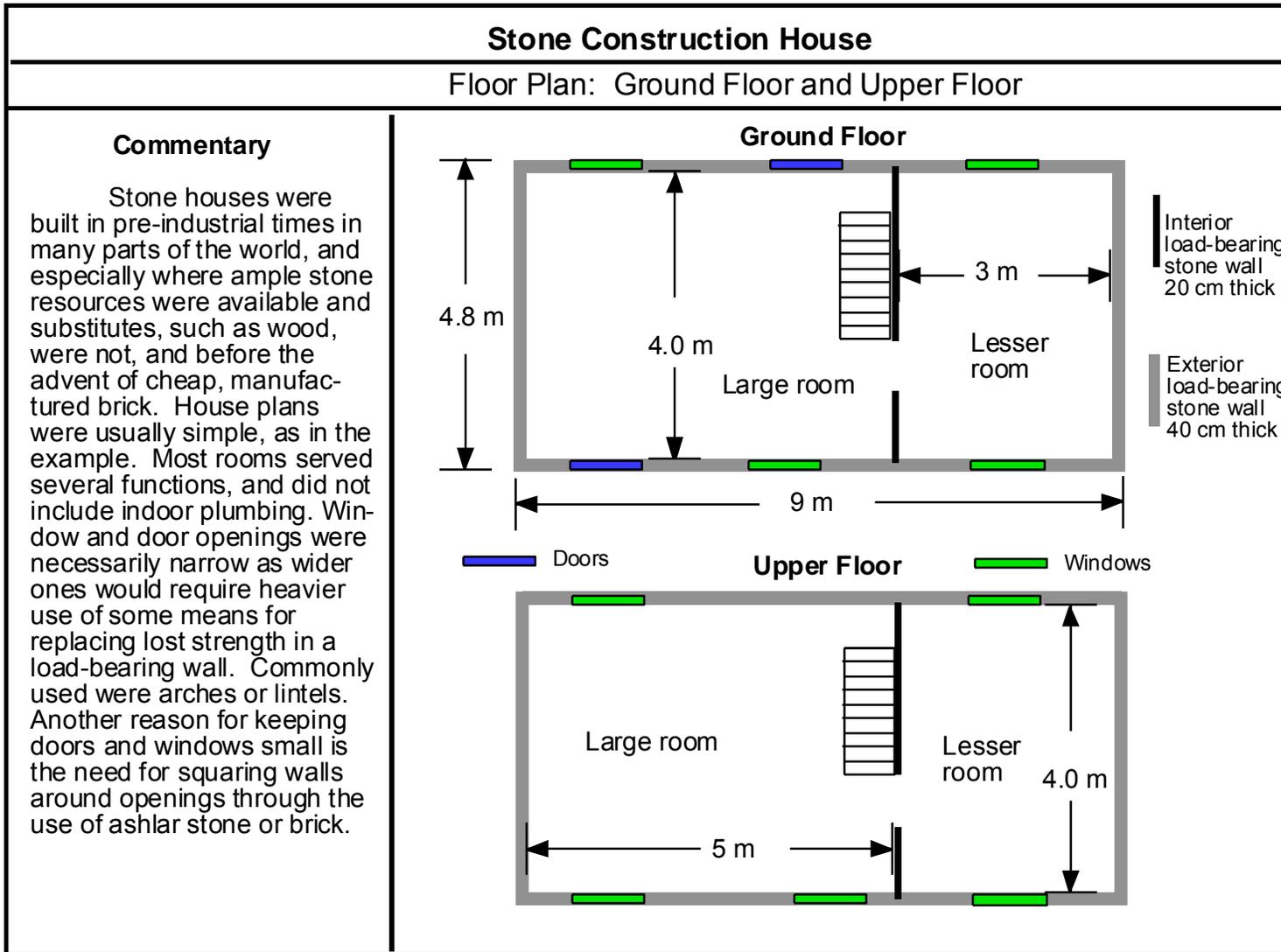


Figure 30. Mass 1-3-a floor plans.

Mass 1-4 Construction

Stone Construction House

700-Year-Old Buildings, Italy

Stone House Construction Examples



RE Photo



RE Photo

Commentary:

Immediately striking in these views of old stone houses is the mix of exposed building materials. A few ashlar stones are visible, used particularly for squaring building corners, in arches, and around doors and windows. Also visible are indications of wall repair over the centuries involving rubble stone, brick, and parts of ashlar stone. Wall thickness of around 40 cm is visible in the doorway and window in the right frame.

Figure 31. Mass 1-4 construction.

Mass 2-1 Place on Building Construction Chart

Stone Construction Institutional Buildings

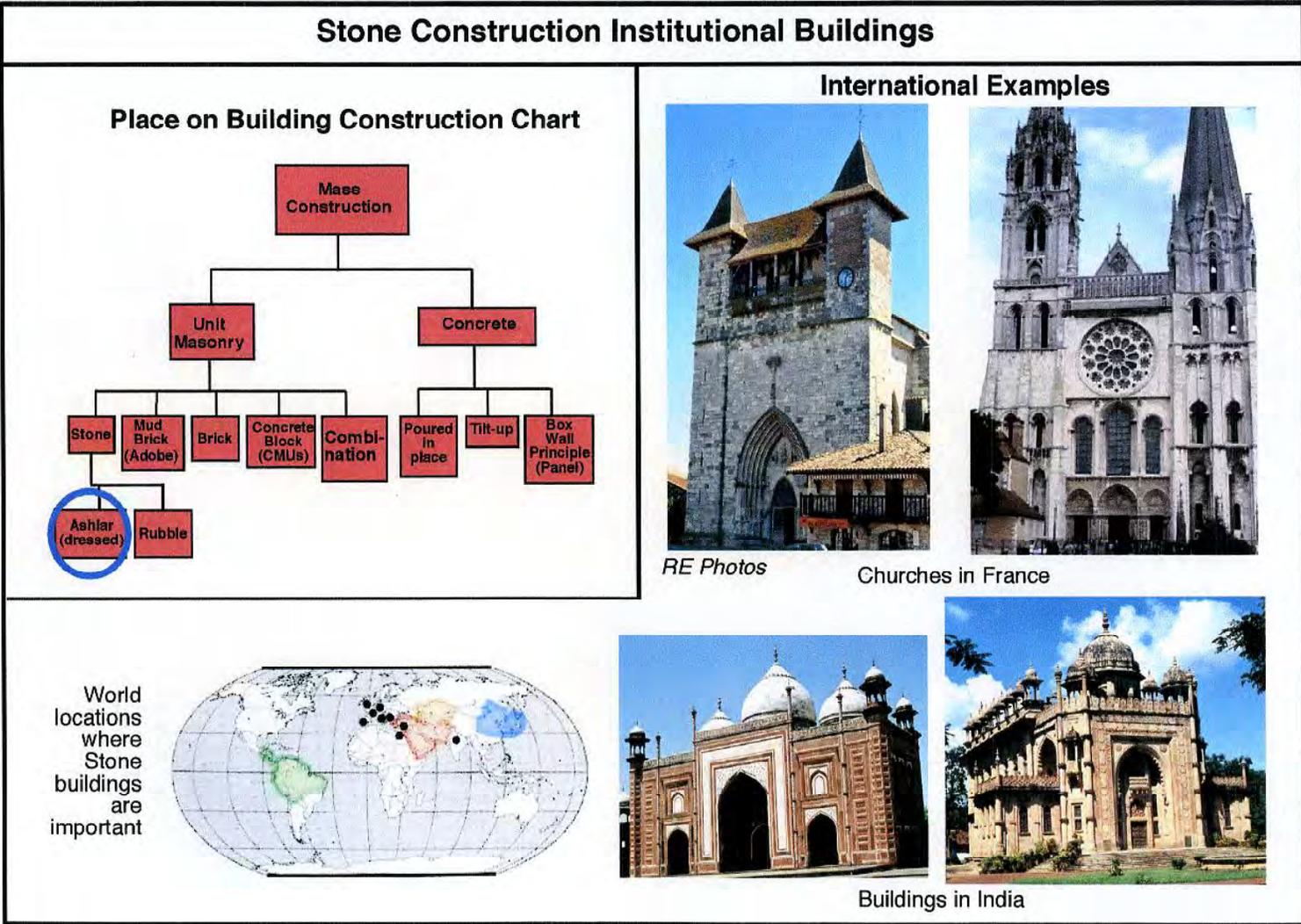


Figure 32. Mass 2-1 place on building construction chart.

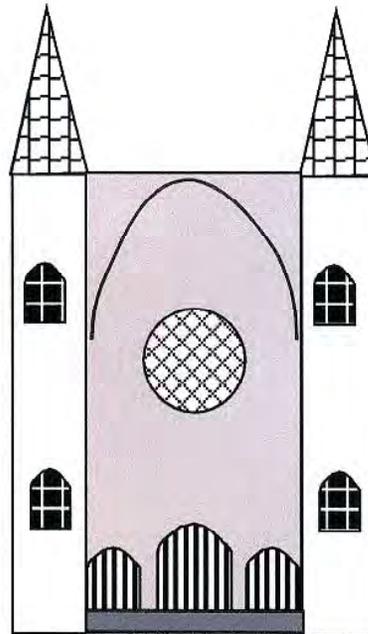
Mass 2-2 Elevations

Stone Institutional Building

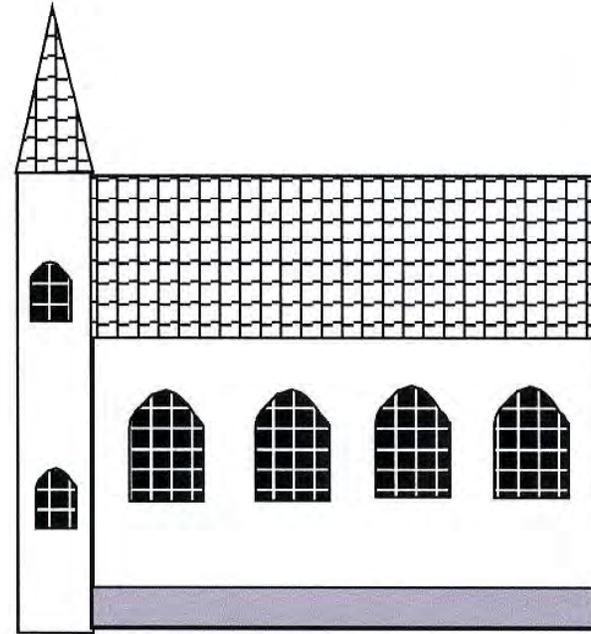


RE Photo

A church in France.



Front Elevation



Side Elevation

Commentary

Shown here is a stylized example of a classic European church. Many stone structures were constructed over a period of several hundred years, ranging in architectural style from Roman through Gothic. The photo example is of a church in France. Windows employed small panes, often of stained glass. Dimensions are not included considering the great variation in extant examples.

Figure 33. Mass 2-2 elevations.

Mass 2-3 Floor Plan

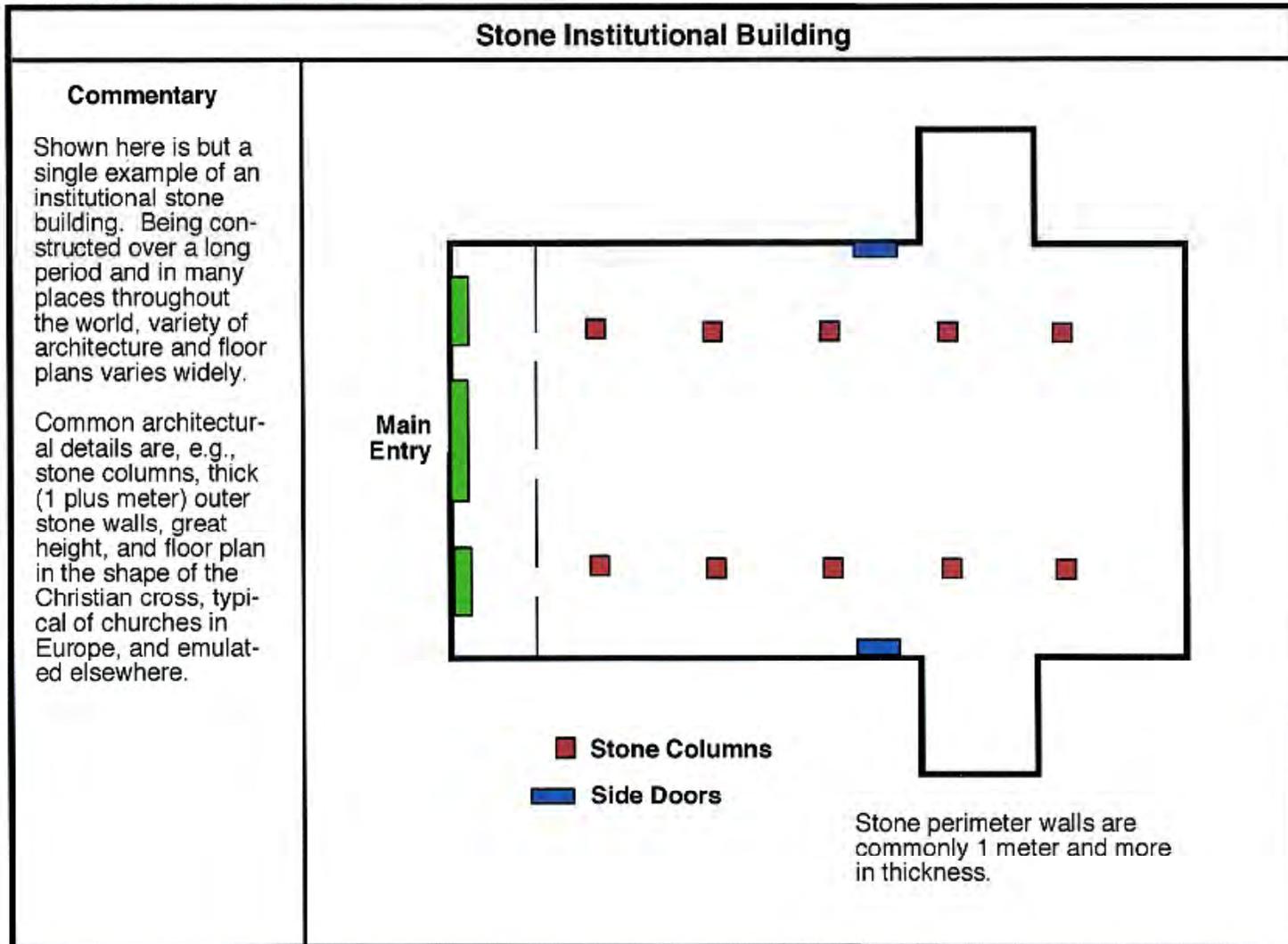


Figure 34. Mass 2-3 floor plan.

Mass 2-4-a Construction

Stone Construction Institutional Buildings



RE Photo

This building (in Tunis, Tunisia) provides a good example of the use of ashlar (dressed) stone in conjunction with rubble (irregular) stone units, the ashlar (being much more expensive and requiring intensive labor with simple tools) used to square corners while the irregularities of the rubble stone are compensated through use of ample quantities of grout.

Rubble stone theoretically offers less resistance to a munition than would the fitted ashlar stone.

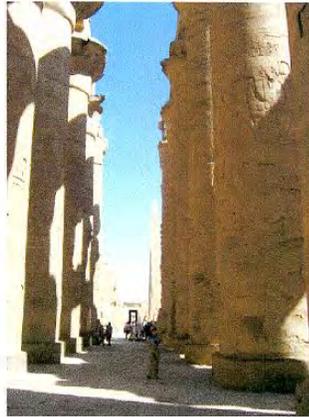


RE Photo

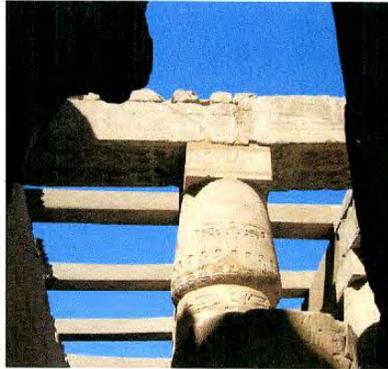
This wall (in a building in London) uses three different materials to offset the irregularities of rubble stone: ashlar units at the wall end, concrete near and at the top, and brick to form an arch at the window. Note the remnants of a pilaster, part in rubble stone and part in ashlar stone.

Mass 2-4-b Construction

Use of Stone in Ancient Egypt (in Luxor)



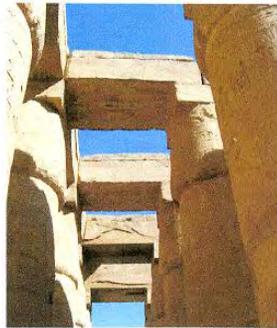
A



B



C



D



E



F

RE Photos

Commentary

Basic principles of stone construction are illustrated here. Stone has great compressive strength but little tensile strength. Thus, beams (lintels) could not be very long without encountering their bending moments and breaking. Short beams demanded closely spaced columns that, in order to achieve great height, had to have wide girth at their bases. A: large, closely spaced columns. B: Extant beams once had wooden joists to support a roof. C: Long beams are composed of shorter beams, as seen in D and E. F: A true mass construction stone room, albeit small.

Figure 36. Mass 2-4-b construction.

Mass 2-4-c Construction

Principles Concerning Stone Walls



China's Great Wall manifests the principle that a wall exterior will employ ashlar (dressed) stone while rubble stone is used in the interior. The roadway on the wall top, on the right, has disintegrated to the point where vegetation is growing in the exposed soil. Note the use of brick for the castellated walls. *RE photo*



The rubble stone wall, on the left, was covered with thin sheets of stone to give the appearance of ashlar stone. Wall is in Greece. *RE photo.*



Stone walls, as is also true of brick walls, are thicker at the base to support loads than they are above. *RE photo*

Figure 37. Mass 2-4-c construction.

Mass 3-1 Place on Building Construction Chart

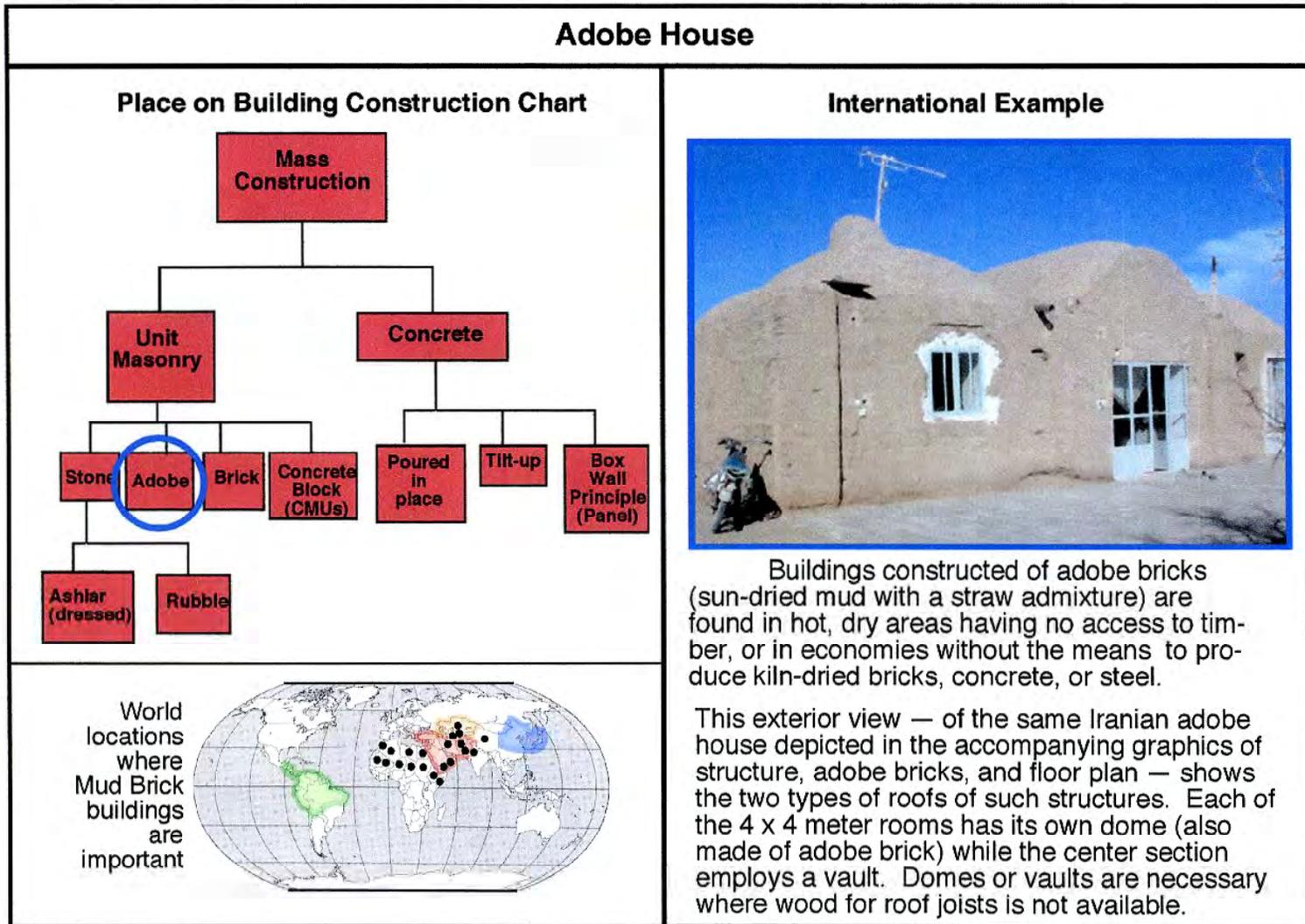


Figure 38. Mass 3-1 place on building construction chart.

Mass 3-2-a Elevation and Isometric Rendering

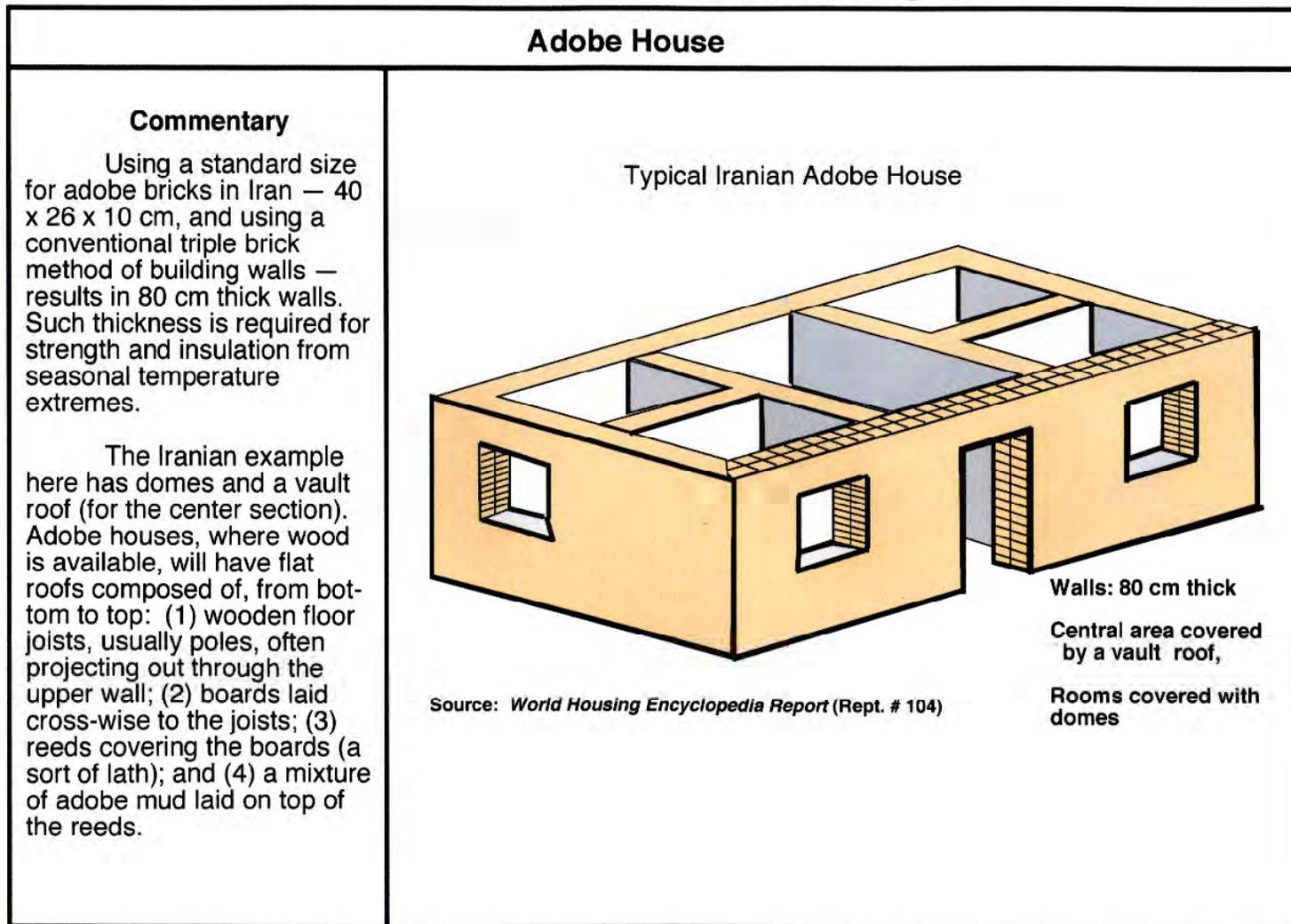


Figure 39. Mass 3-2-a elevation and isometric rendering.

Mass 3-2-b Elevations

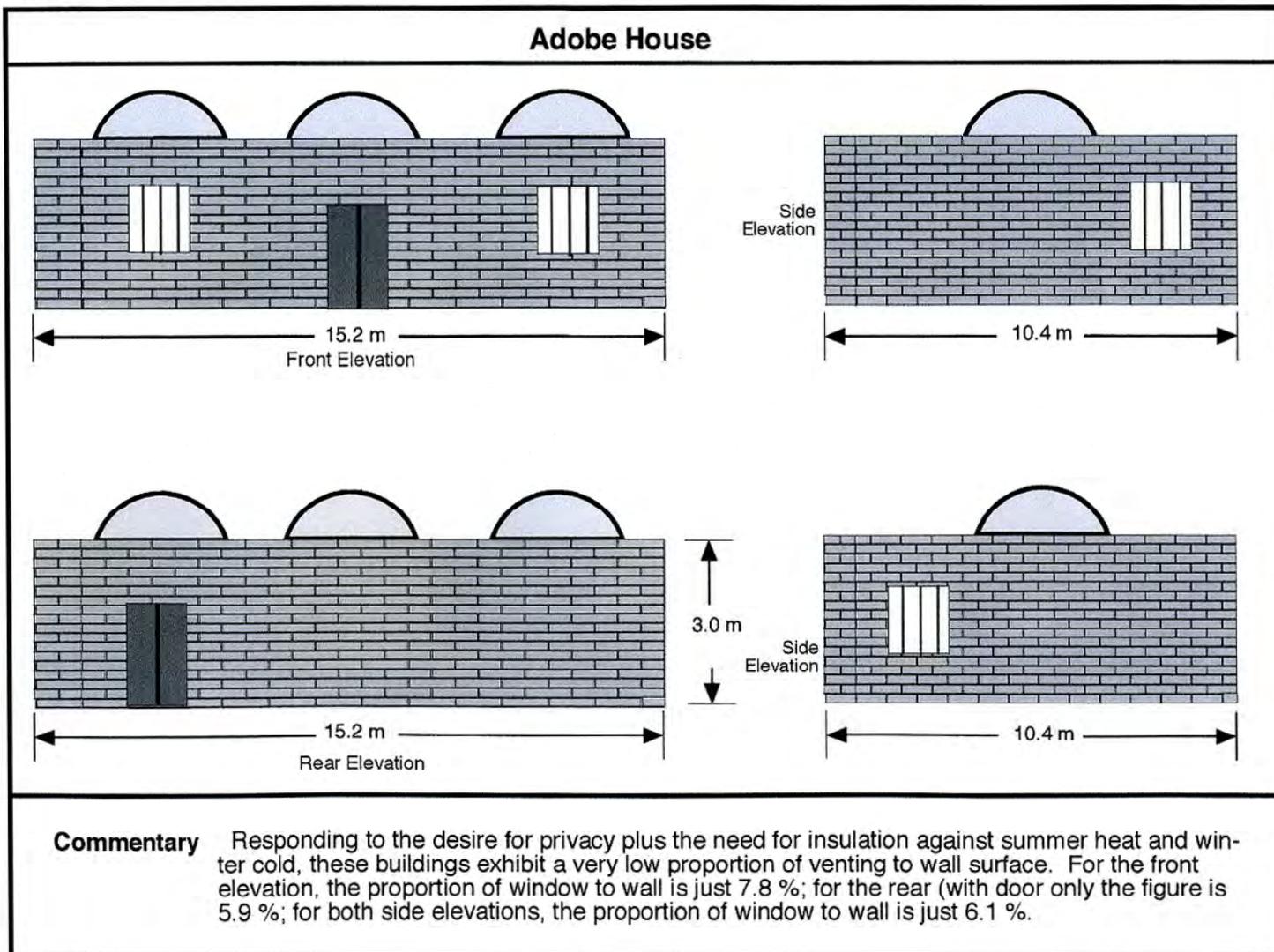


Figure 40. Mass 3-2-b elevations.

Mass 3-3-a Floor Plan

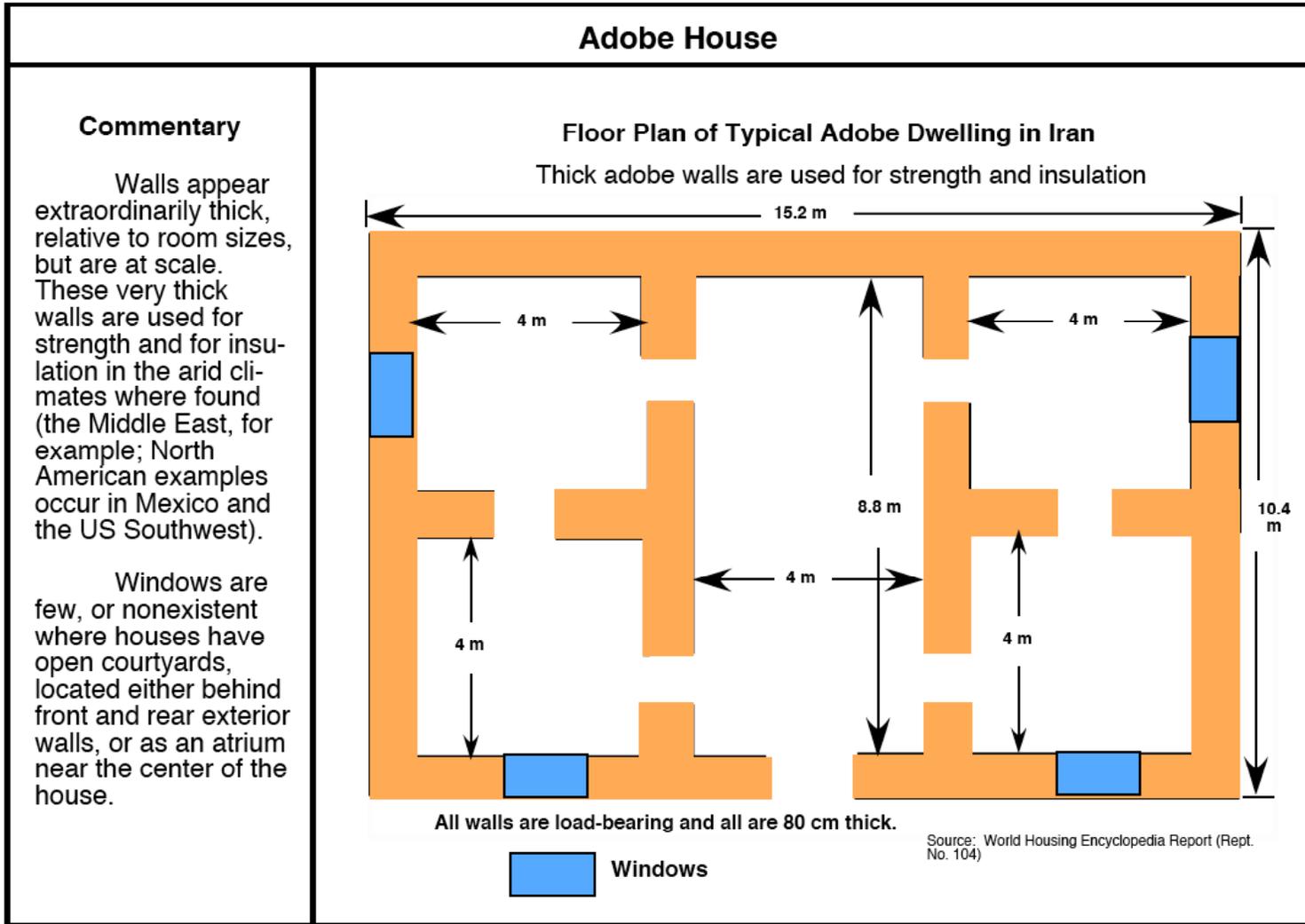


Figure 41. Mass 3-3-a floor plan.

Mass 3-4-a Construction

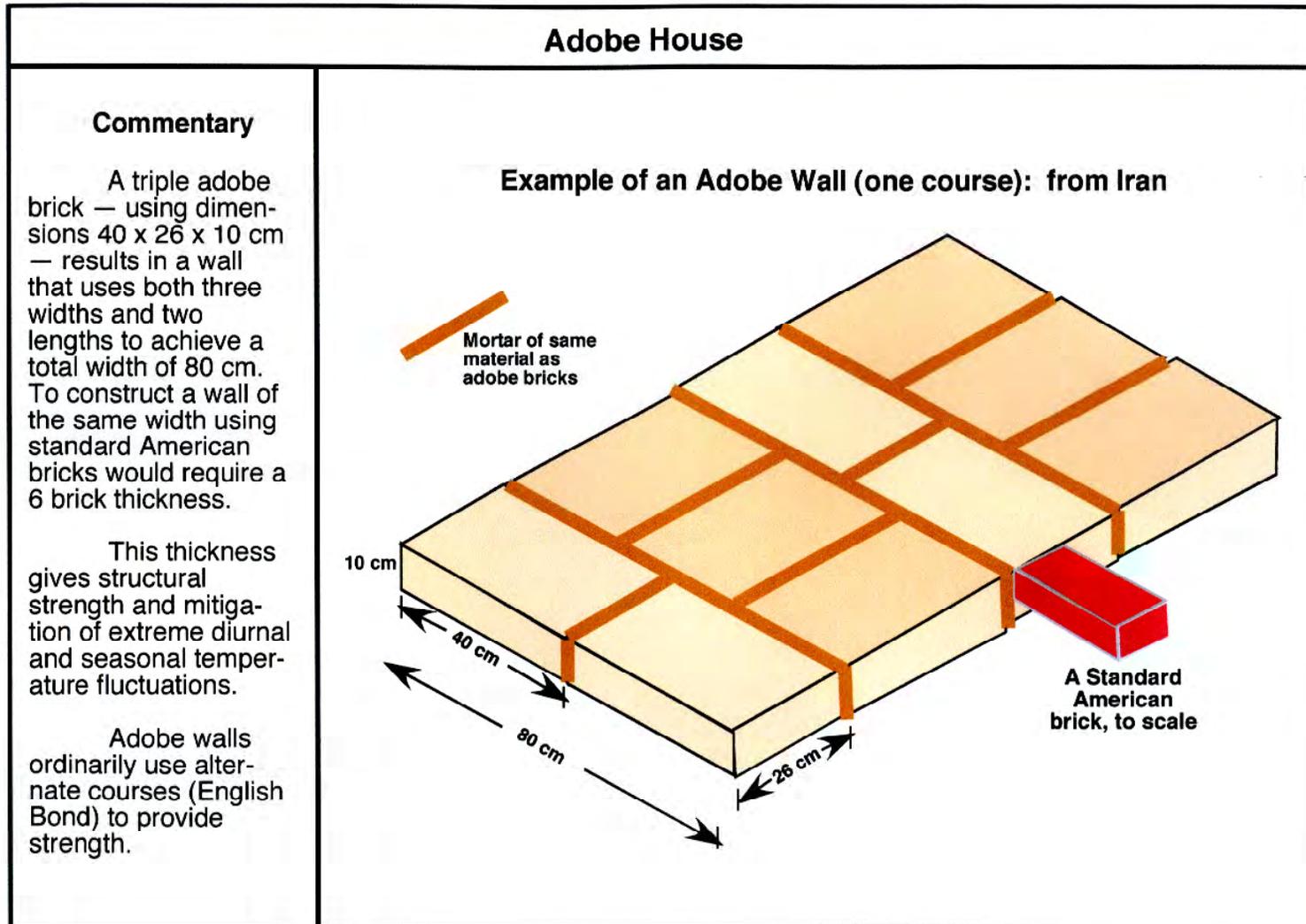


Figure 42. Mass 3-4-a construction.

Mass 3-4-b Construction Method

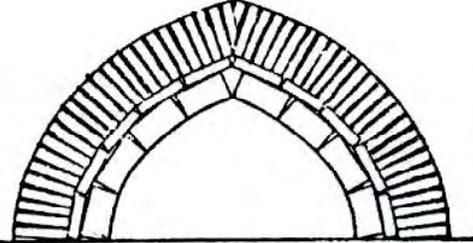
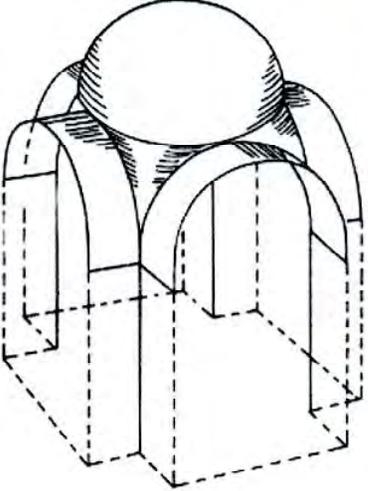
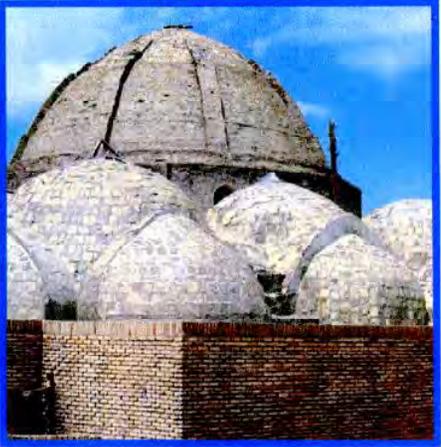
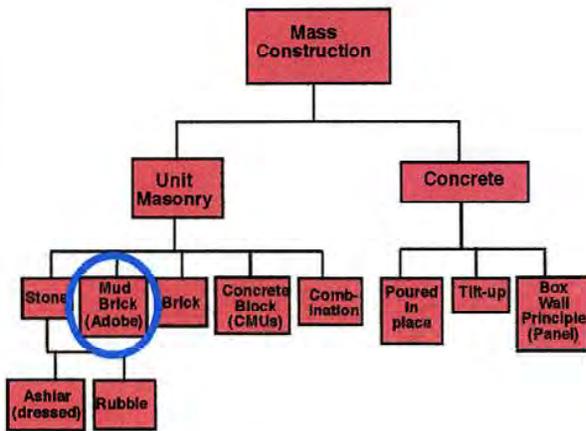
Adobe House		
<p style="text-align: center;">Simple Islamic Arch</p> 	<p style="text-align: center;">Vaults and a Dome</p> 	<p style="text-align: center;">Example Large and Small Domes in a Suq (Market Place)</p> 
<p>Commentary</p>	<p>The adobe house (see photo on Mass 3-1) has both an arch for the center rooms and domes for each of the small 4 x 4 meter rooms. They were constructed in the way illustrated above. The basic form is the arch, used throughout time for many forms of construction, e.g., bridges, and given regional character, e.g., the Roman arch, in many parts of the world. The arch is then expanded into linear shaped vaults, or the gores are brought together to form domes. These methods succeed in enclosing space through the device of a brick roof.</p>	

Figure 43. Mass 3-4-b construction method.

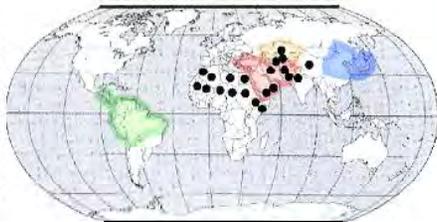
Mass 4-1 Place on Building Construction Chart

Mud Brick Single Floor Store

Place on Building Construction Chart



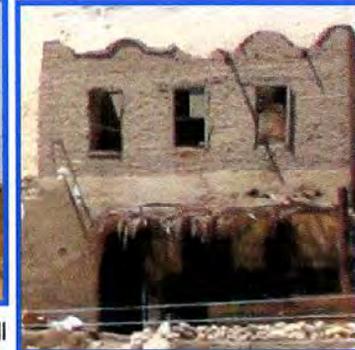
World locations where Mud Brick buildings are important



Mud Brick Structural Examples, Luxor, Egypt



Profile of a plaster-covered external wall (thickness: 48 cm)



A two story example. Note wood frames in windows to offset irregularly shaped mud bricks



Floor/ceiling joists placed in mud brick wall.



Exposed supports for floor/ceiling joists. Note wall thicknesses.

RE Photos Egypt 2004

Figure 44. Mass 4-1 place on building construction chart.

Mass 4-2 Elevations

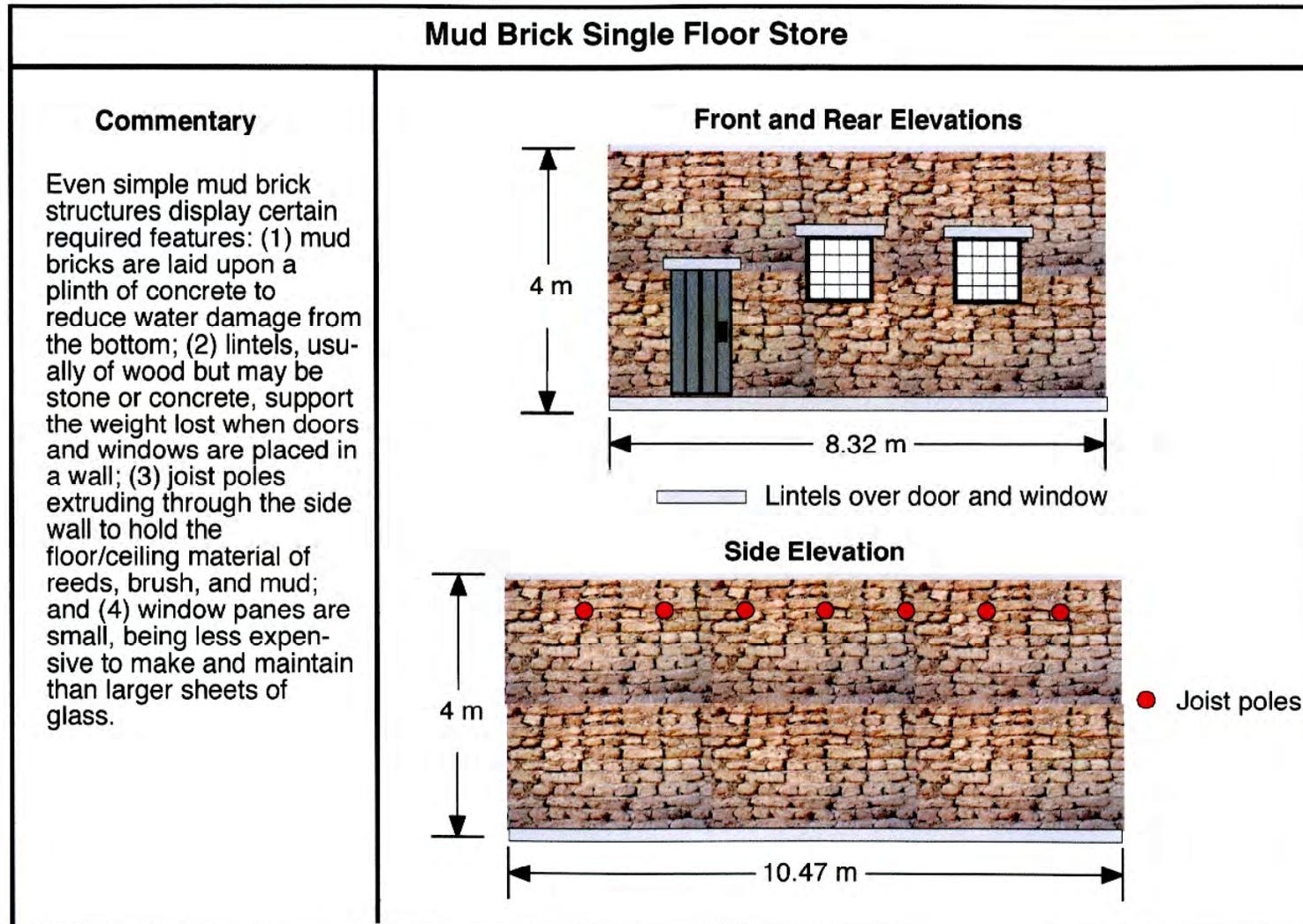


Figure 45. Mass 4-2 elevations.

Mass 4-3-a Floor Plan

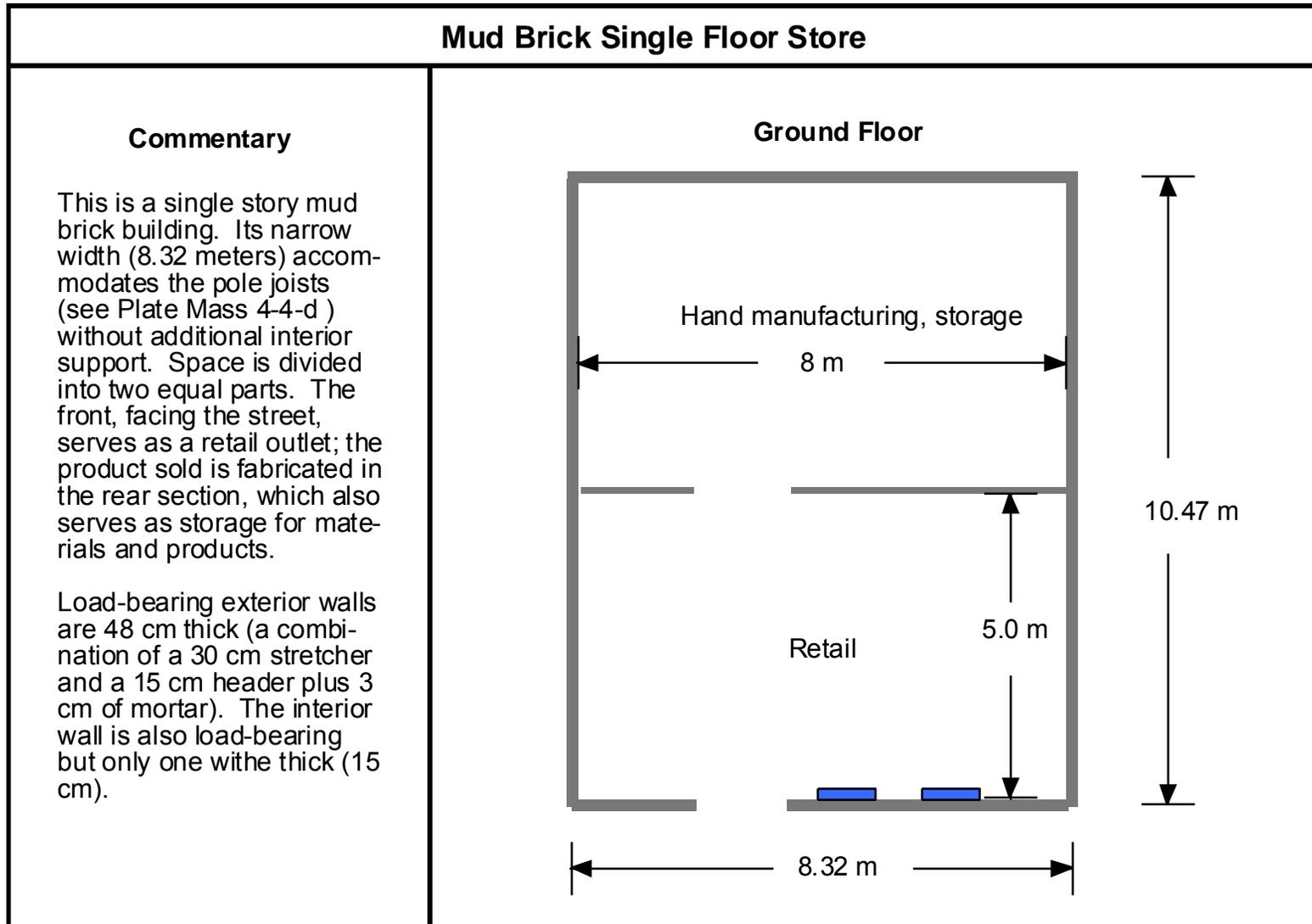


Figure 46. Mass 4-3-a floor plan.

Mass 4-4-a Construction: Building Materials

Mud Brick Single Floor Store

Mud Brick Examples: Egypt 2004



A Quadruple Mud Brick Wall



Close-up of Mud Brick Wall
Using English Bonding



Straw in Mud Brick, added for Strength

Commentary

The character of mud brick is revealed here. Bricks are uneven in shape, and courses are not laid neatly as is the practice with kiln-dried brick. However, English bond (alternate courses of stretchers and headers) is commonly used. Straw, used to strengthen the clay, is exposed in many instances. This quadruple brick wall (in Luxor, Egypt) is about 66 cm in thickness. *RE Photos 2004.*

Mass 4-4-b Construction: Materials

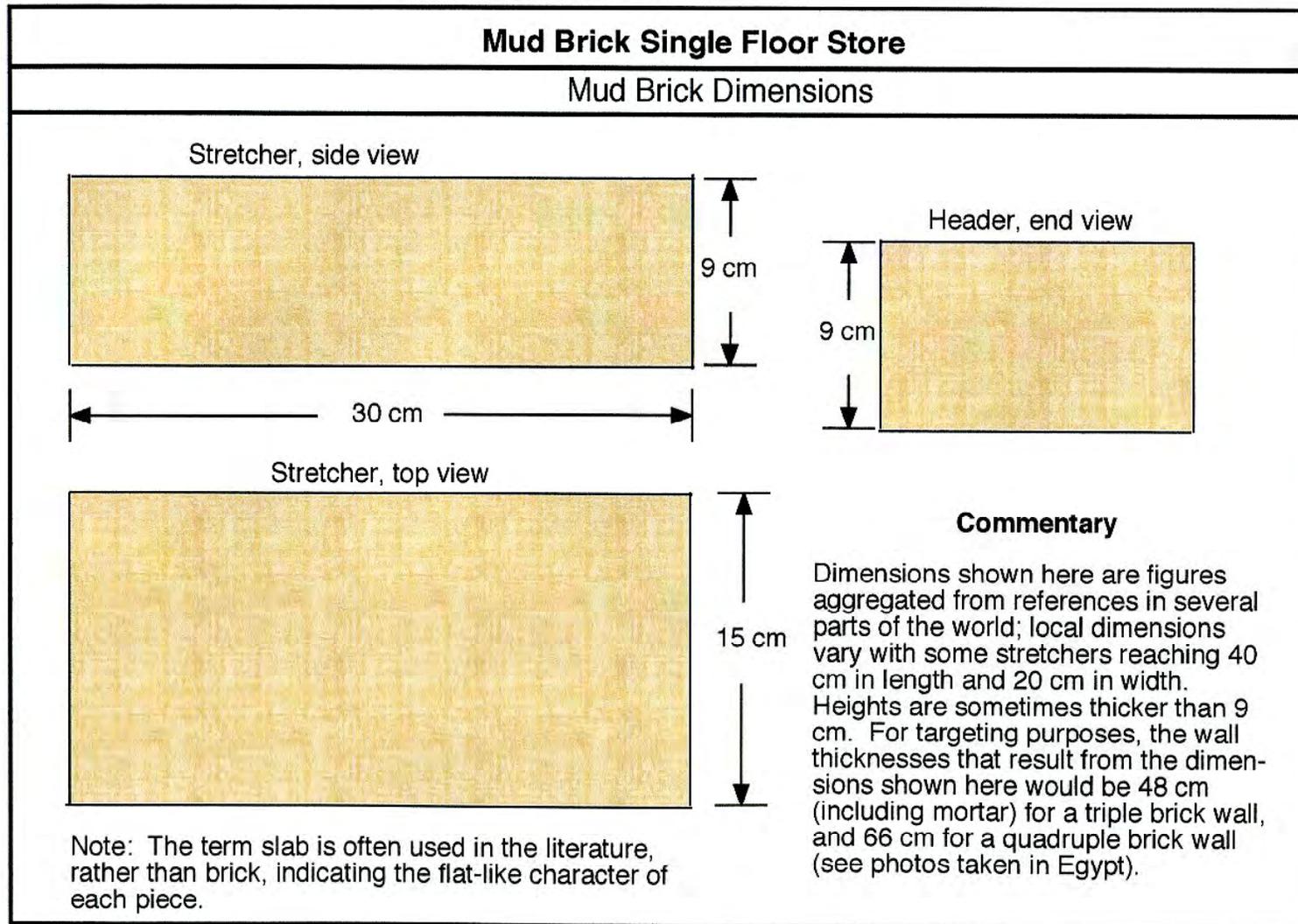


Figure 48. Mass 4-4-b construction: materials.

Mass 4-4-c Construction: Materials

Mud Brick Single Floor Store

Commentary

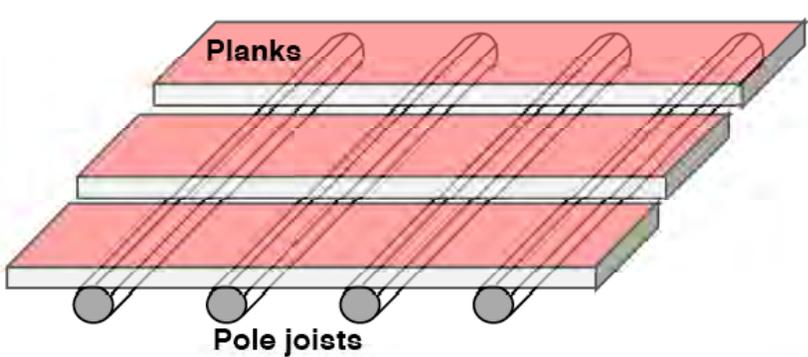
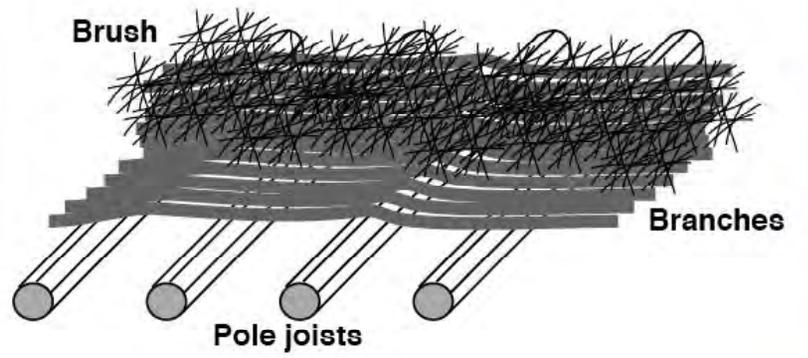
Two stages of mud brick making are visible here. In the upper part of the group, near the worker, bricks are in an advanced stage of drying: those in the lower area have apparently just been formed and are now beginning the drying process. That mud bricks are larger than kiln dried clay bricks is also evident. The latter are designed so that a mason can span the width of the header (some 4 inches or so) with one hand to place the brick onto the wall being built, while keeping the trowel in the other hand. Mud bricks are definitely too wide to use this technique and must be placed with two hands.

Freshly Made Mud Bricks Drying in the Sun



Figure 49. Mass 4-4-c construction: materials.

Mass 4-4-d Construction: Roof Materials

Mud Brick Single Floor Store	
Floor/ceiling and Roof Details	
 <p>A 3D perspective diagram showing three parallel wooden planks resting on four cylindrical pole joists. The planks are colored light red, and the joists are grey. Labels 'Planks' and 'Pole joists' are present.</p>	<p>Commentary Mud brick construction uses local wood materials for ceiling/floors (for multi-story buildings); planks are placed across pole joists. Roofs also use pole joists but these are covered first with irregular branches, then brush. These are then plastered with mud to keep out the weather. Flat roofs are the mode in the dry climate areas where mud brick construction is common; the roof is often used for sleeping on hot nights.</p>
 <p>A 3D perspective diagram showing a layer of dark, fibrous brush and a layer of grey, irregular branches resting on four cylindrical pole joists. Labels 'Brush', 'Branches', and 'Pole joists' are present.</p>	 <p>A photograph showing a close-up of a wooden structure where several horizontal branches are laid across vertical joists. The branches are irregular in shape and color, ranging from light brown to dark brown. The joists are light-colored wood.</p> <p>Branches placed cross-wise to joists.</p>

70

Figure 50. Mass 4-4-d construction: roof materials.

Mass 5-1 Place on Building Construction Chart

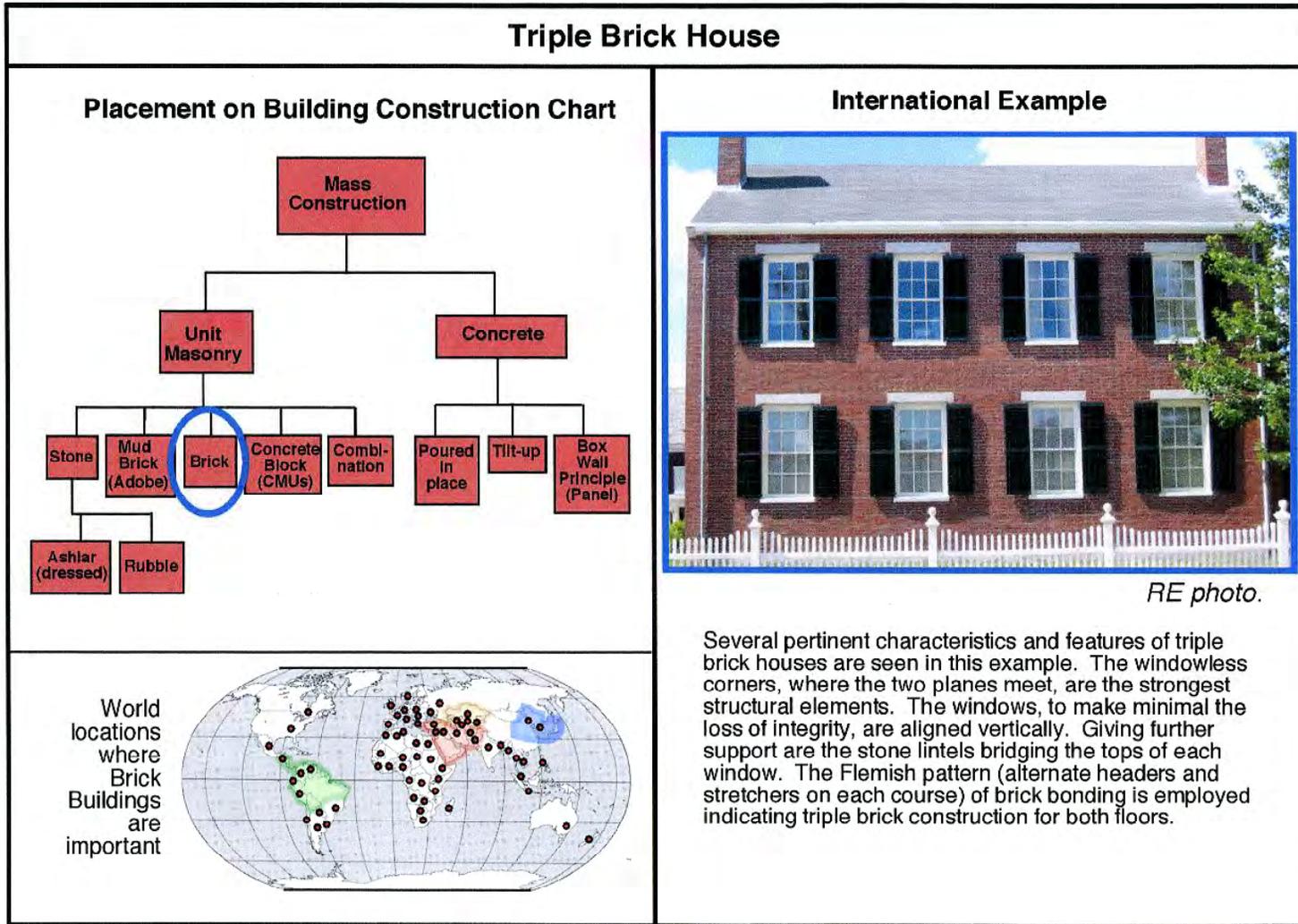


Figure 51. Mass 5-1 place on building construction chart.

Mass 5-2 Elevations

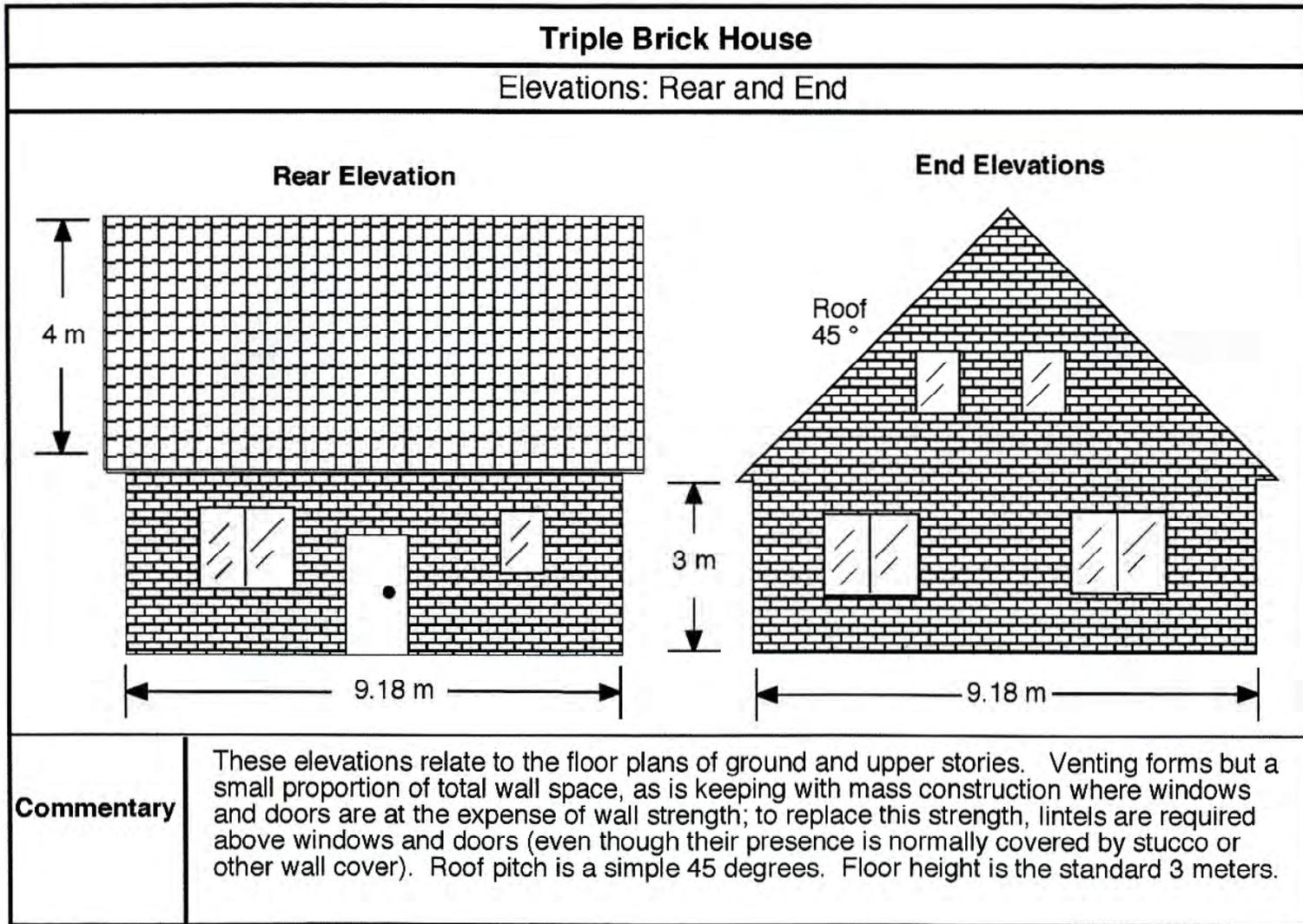


Figure 52. Mass 5-2 elevations.

Mass 5-3-a Floor Plan

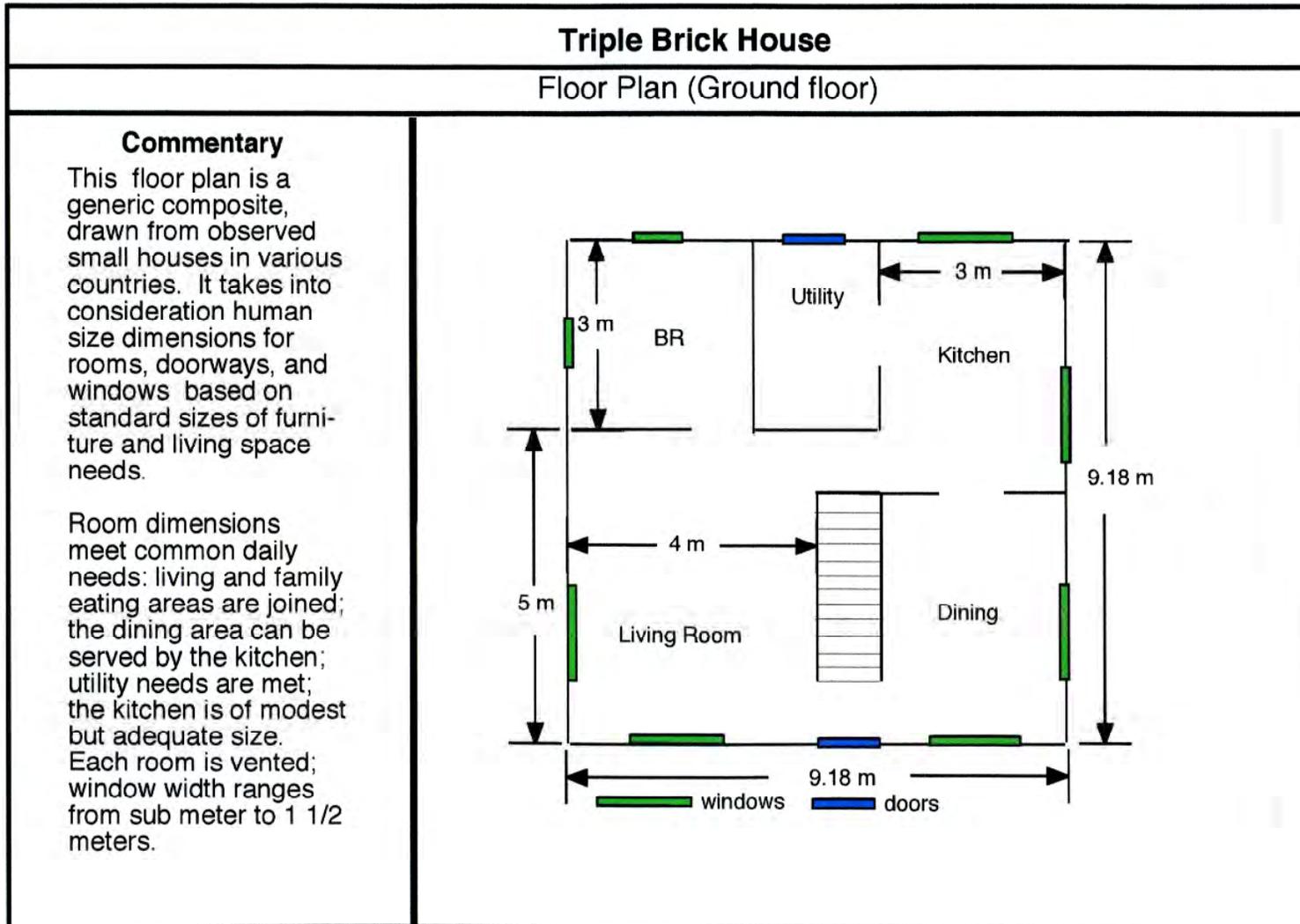


Figure 53. Mass 5-3-a floor plan.

Mass 5-3-b Floor Plan

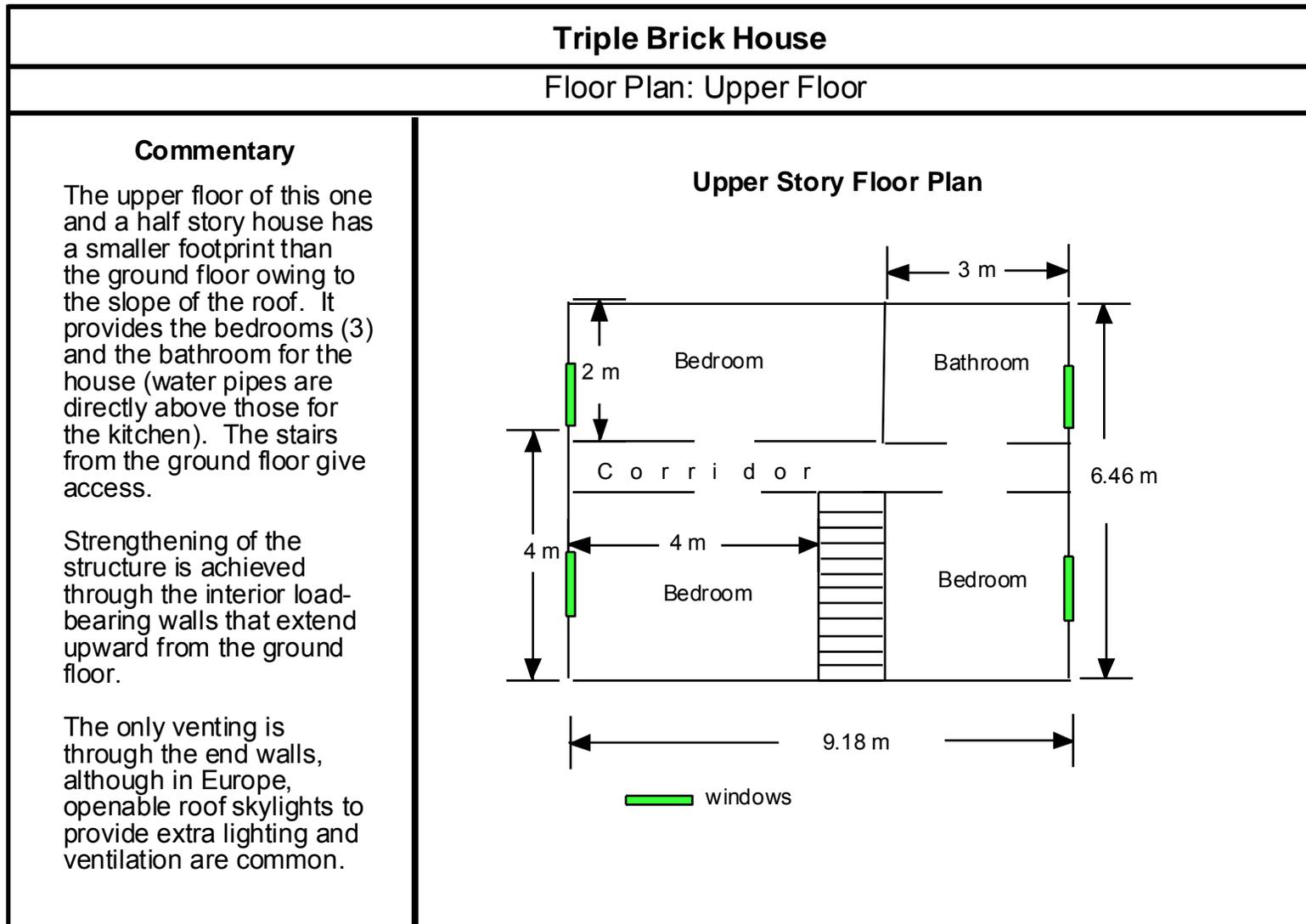
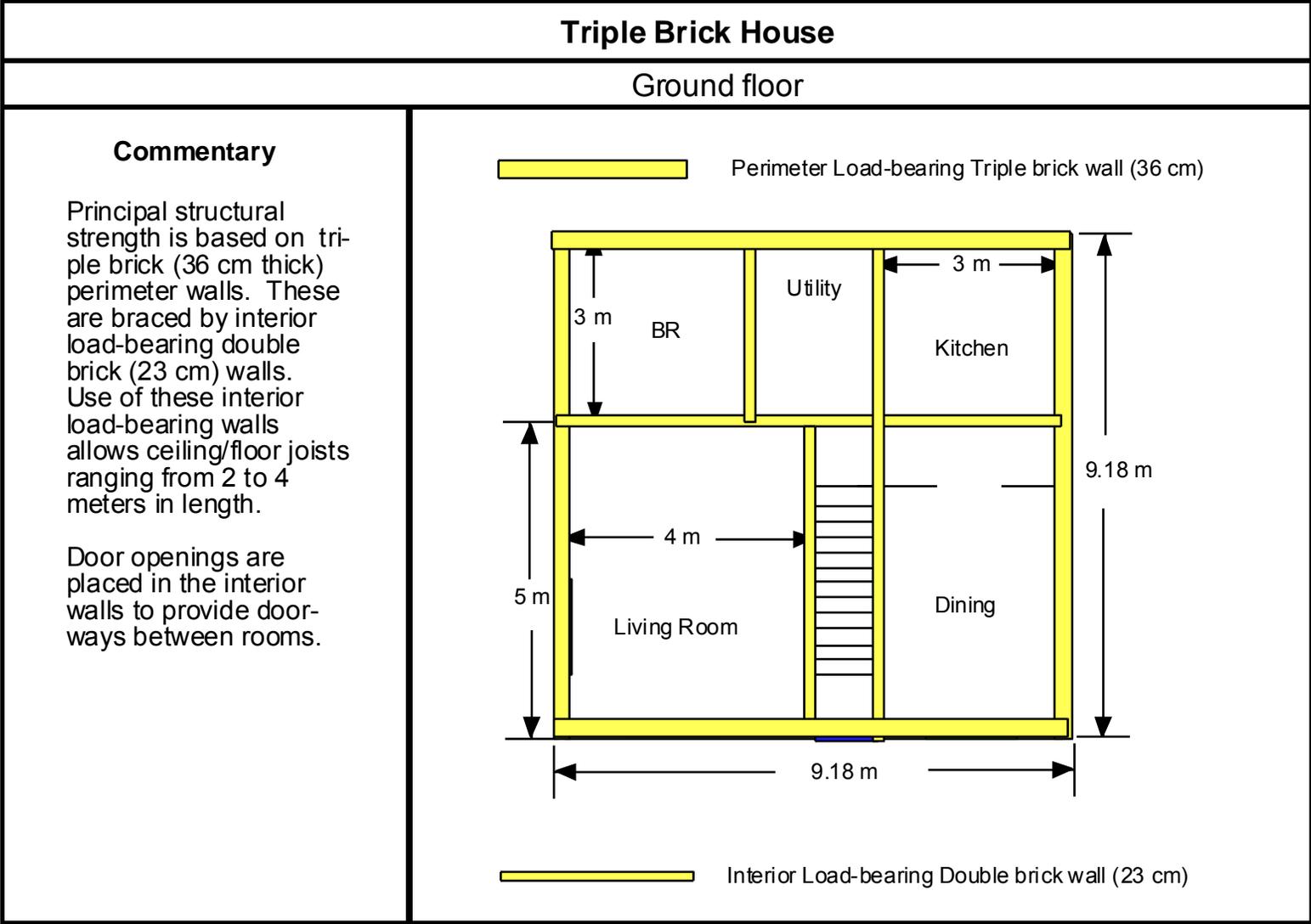


Figure 54. Mass 5-3-b floor plan.

Mass 5-4-a Construction



75

Figure 55. Mass 5-4-a construction.

Mass 5-4-b Construction

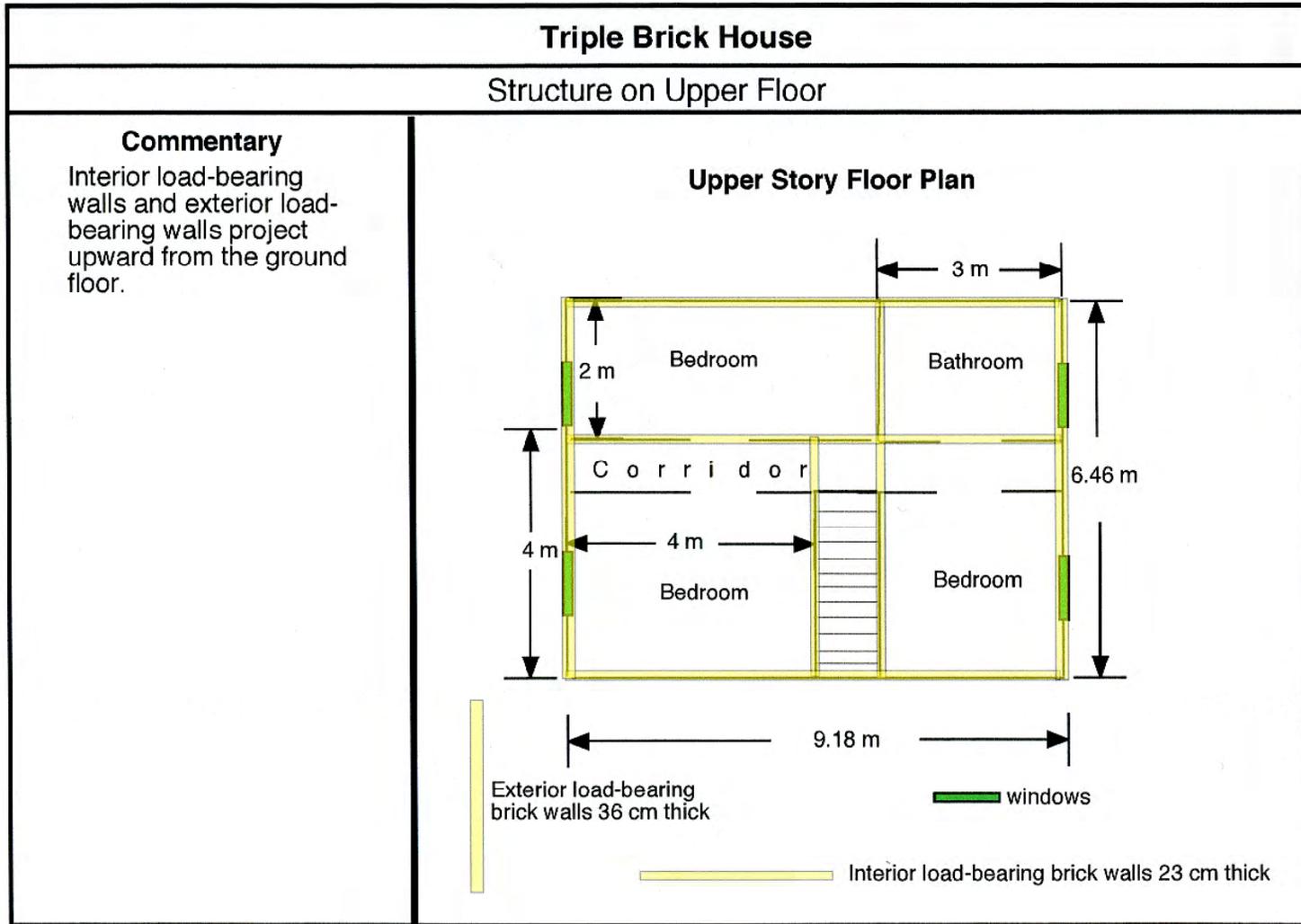


Figure 56. Mass 5-4-b construction.

Mass 5-4-c Construction (Brick Courses)

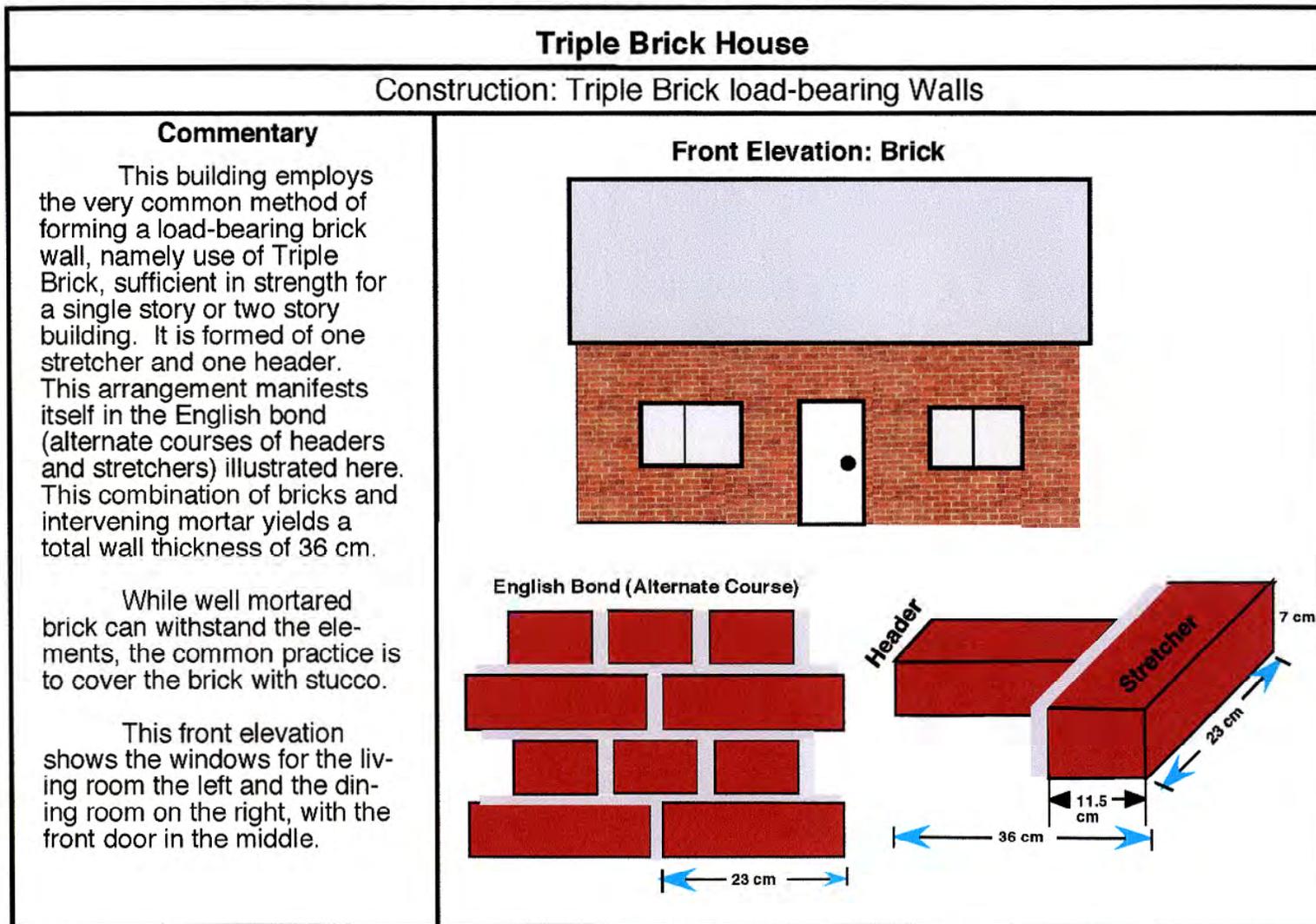


Figure 57. Mass 5-4-c construction (brick courses).

Mass 6-1 Place on Building Construction Chart

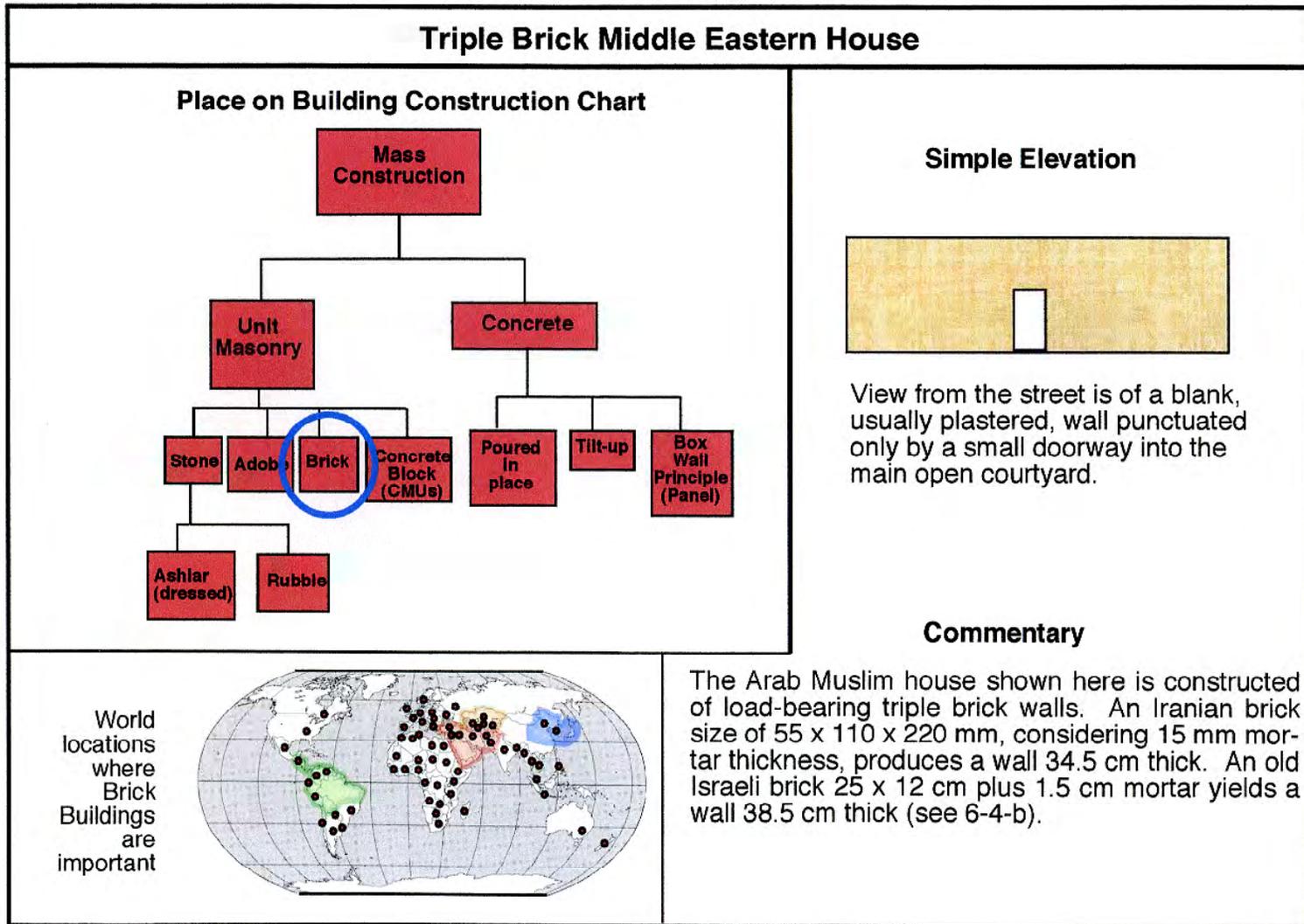


Figure 58. Mass 6-1 place on building construction chart.

Mass 6-2 Elevations

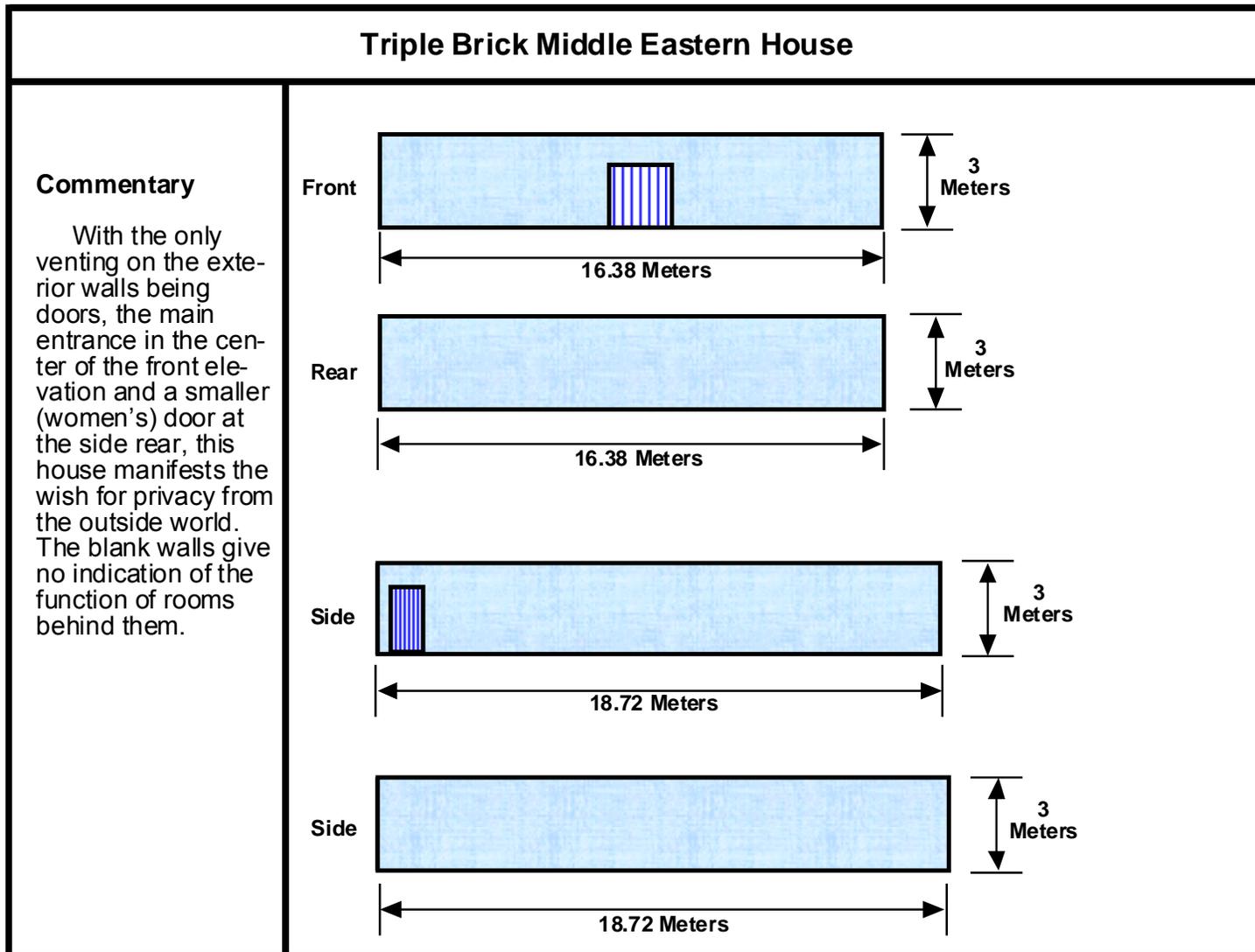


Figure 59. Mass 6-2 elevations.

Mass 6-3-a Floor Plan

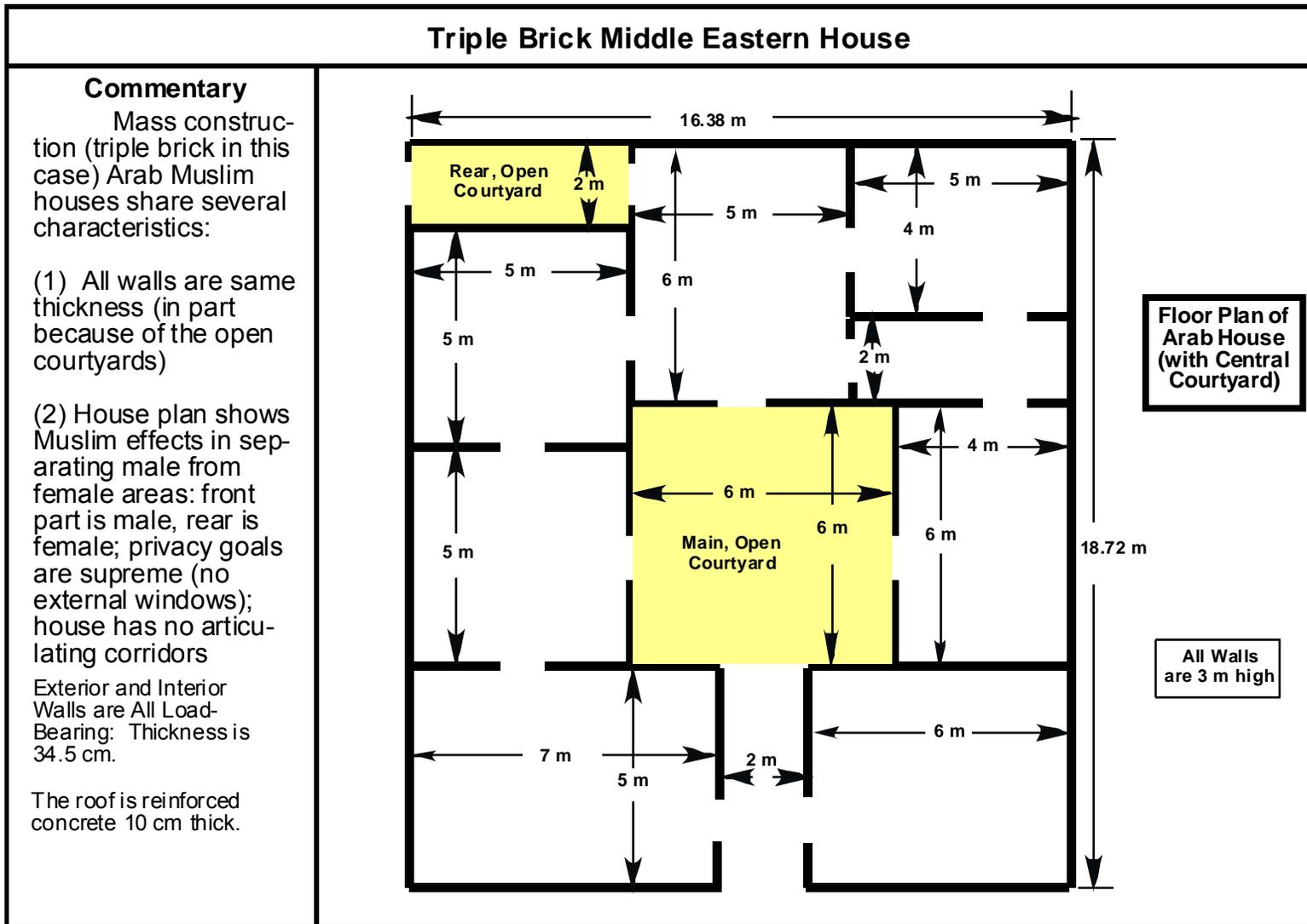


Figure 60. Mass 6-3-a floor plan.

Mass 6-3-b Isometric Floor Plan

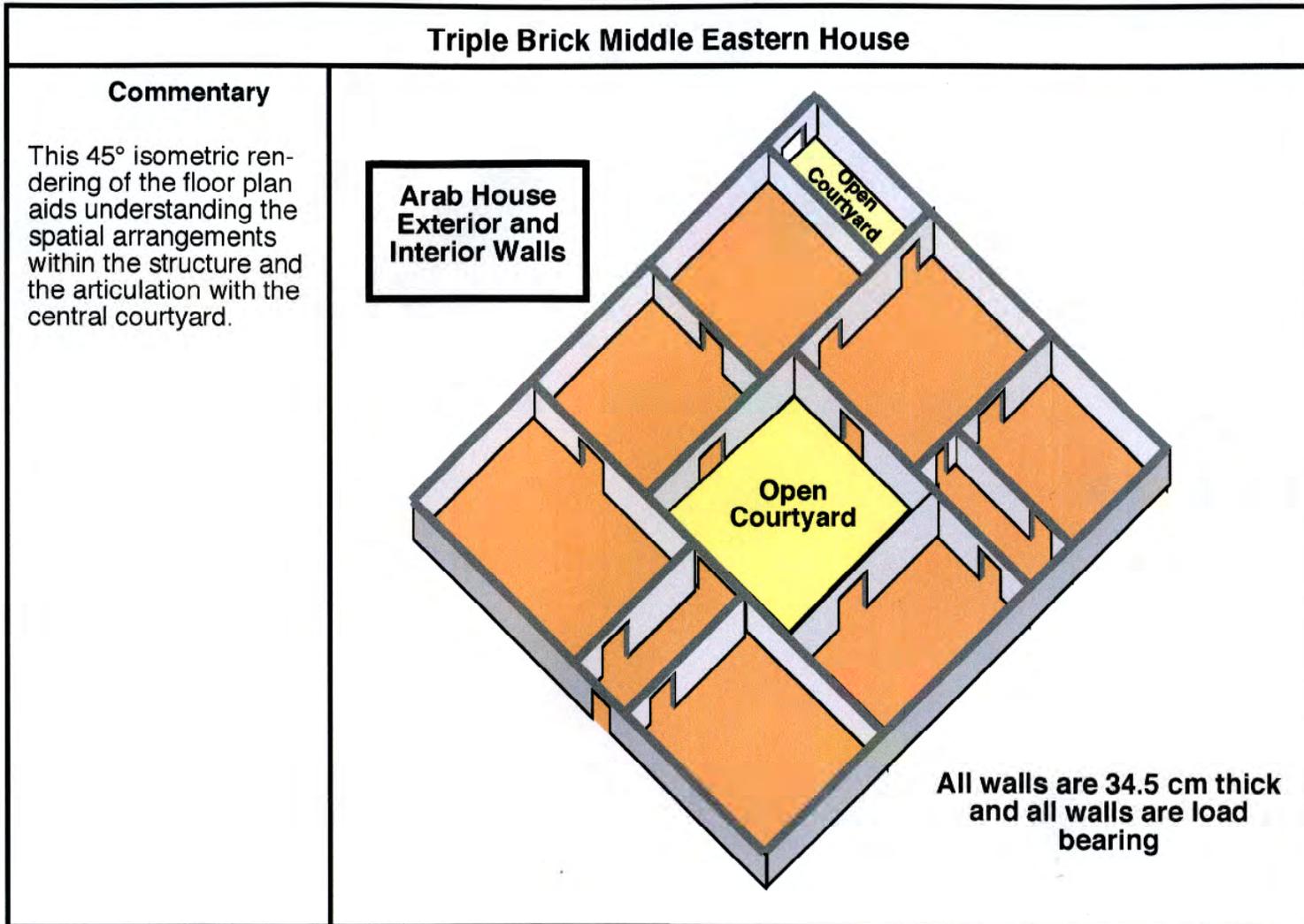


Figure 61. Mass 6-3-b isometric floor plan.

Mass 6-3-c Isometric Floor Plan

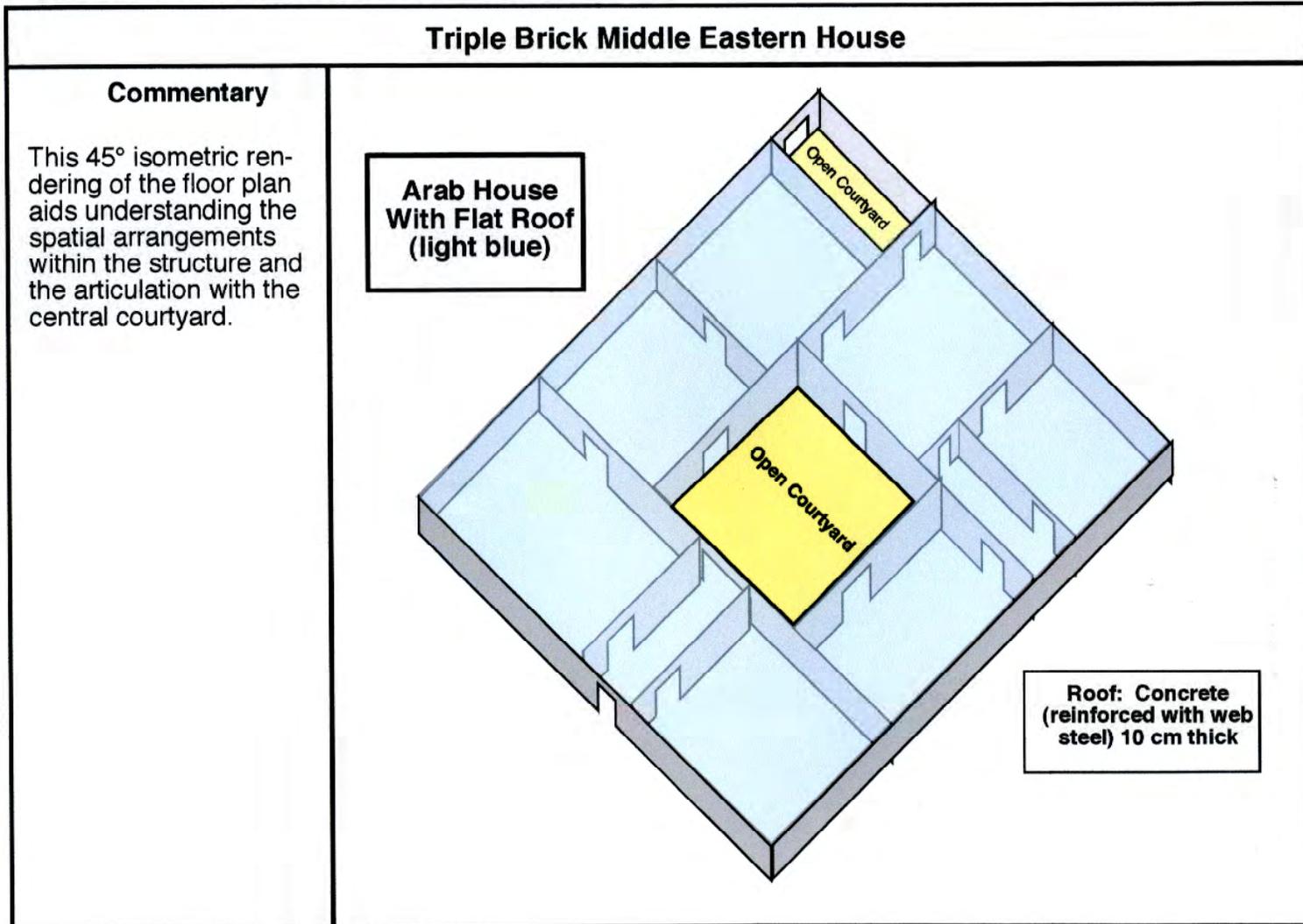


Figure 62. Mass 6-3-c isometric floor plan.

Mass 6-4-a Construction

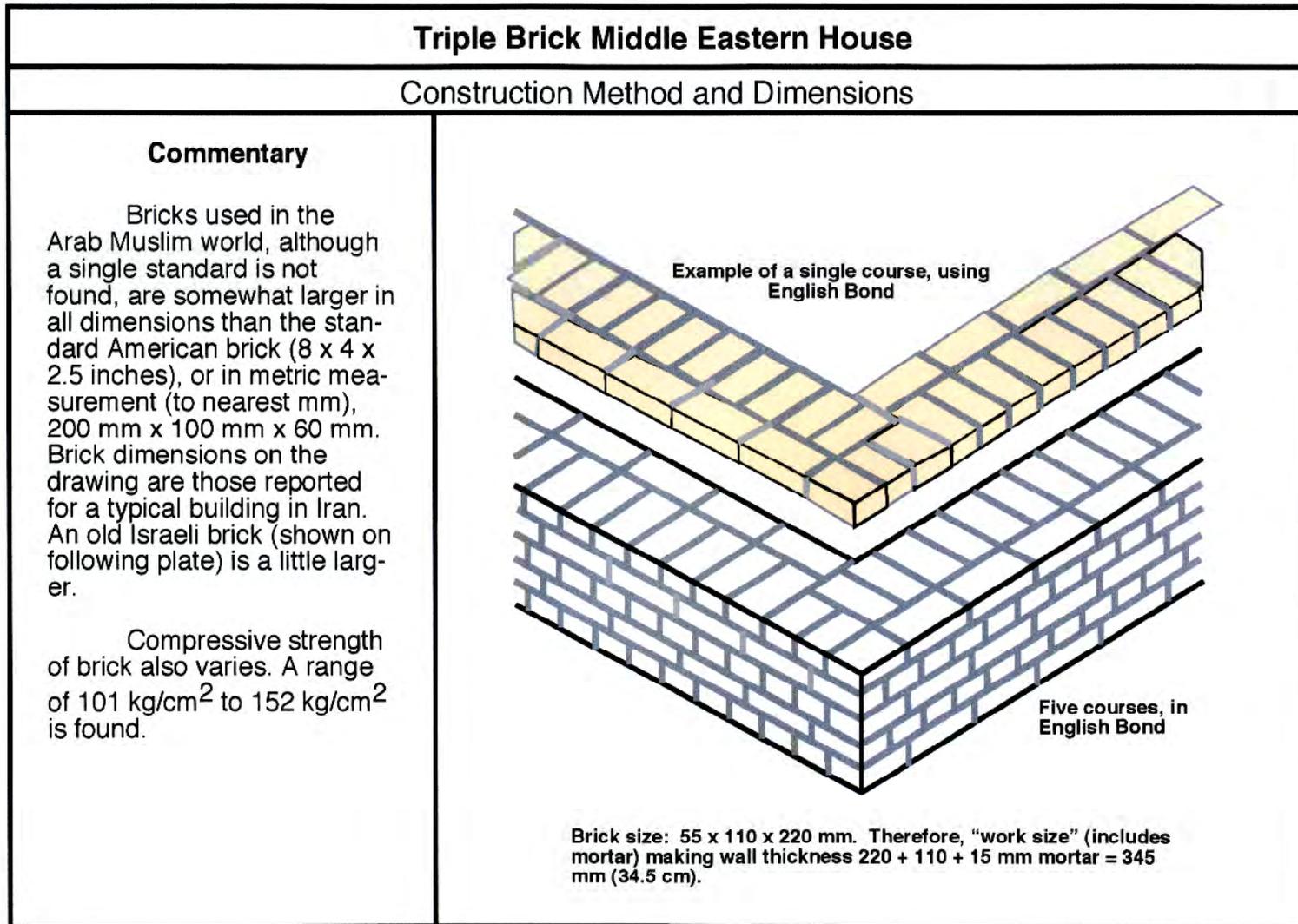


Figure 63. Mass 6-4-a construction.

Mass 6-4-b Construction

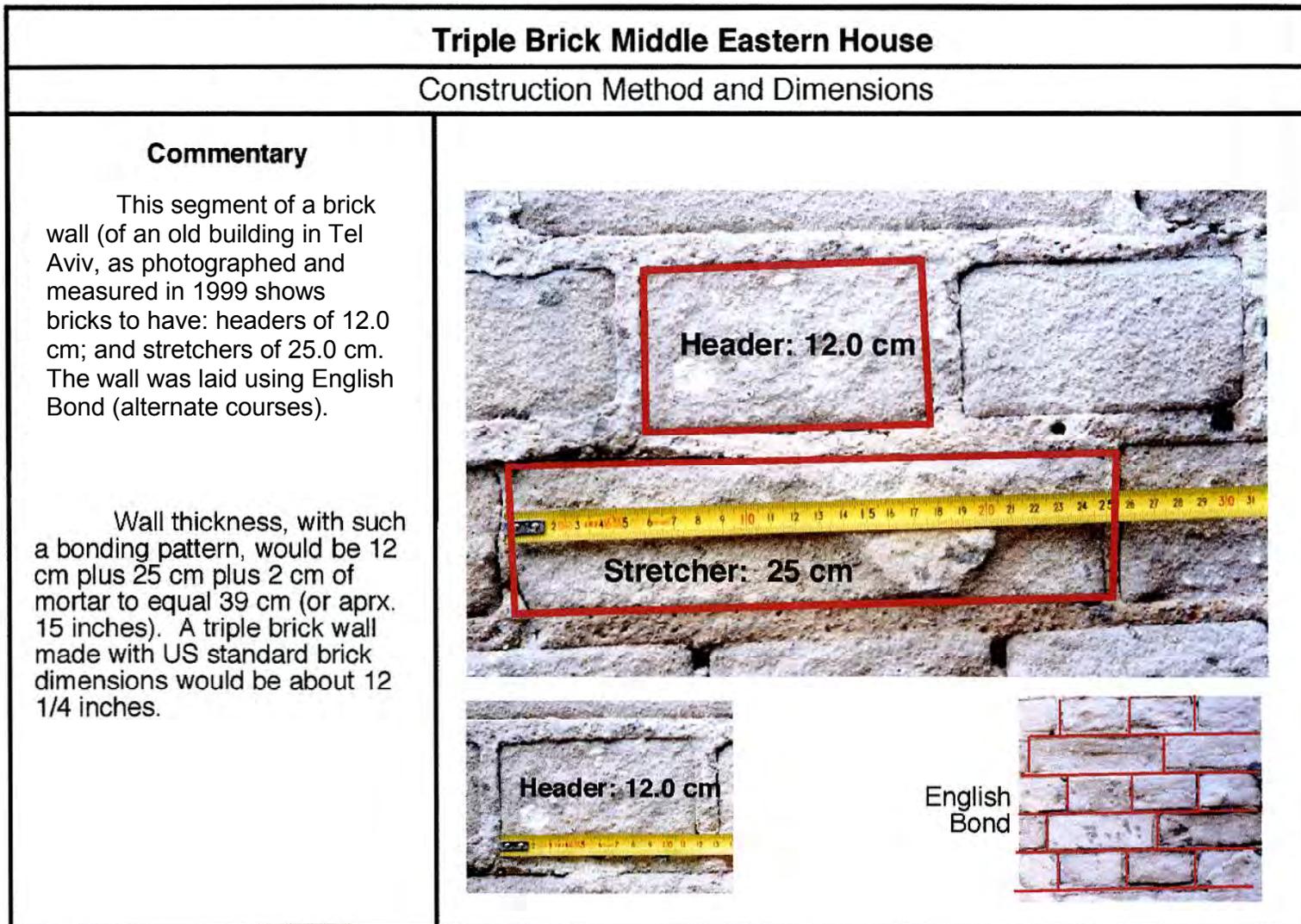
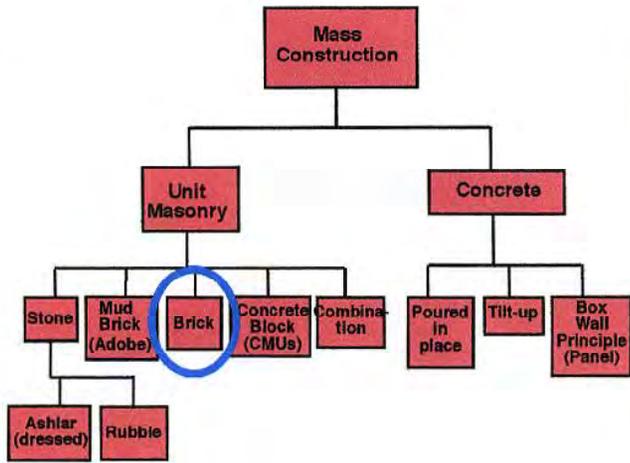


Figure 64. Mass 6-4-b construction.

Mass 7-1 Place on Building Construction Chart

Brick Row House

Place on Building Construction Chart



International Example



RE photo.

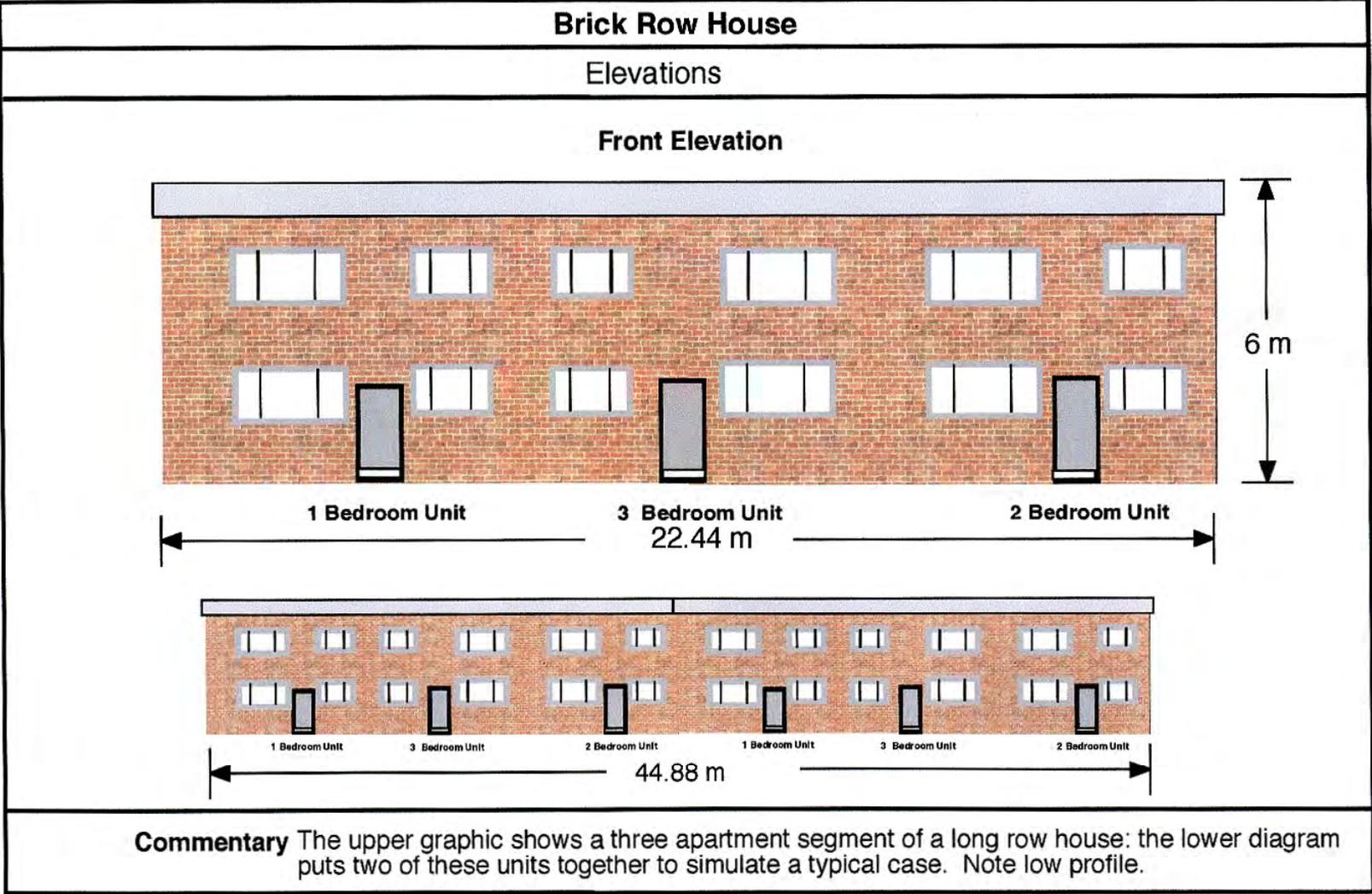
Row houses, such as this example in England, have been a traditional type of housing for a long time. Accordingly, there are many extant examples. Chimneys indicate common wall construction (as opposed to each unit being built separately), and thus load-bearing separating walls are as thin as possible. In the UK, these walls reach through the attic to prevent spread of fire from unit to unit.

World locations where Brick Buildings are important



Figure 65. Mass 7-1 place on building construction chart.

Mass 7-2-a Elevation



98

Figure 66. Mass 7-2-a elevation.

Mass 7-2-b Elevation

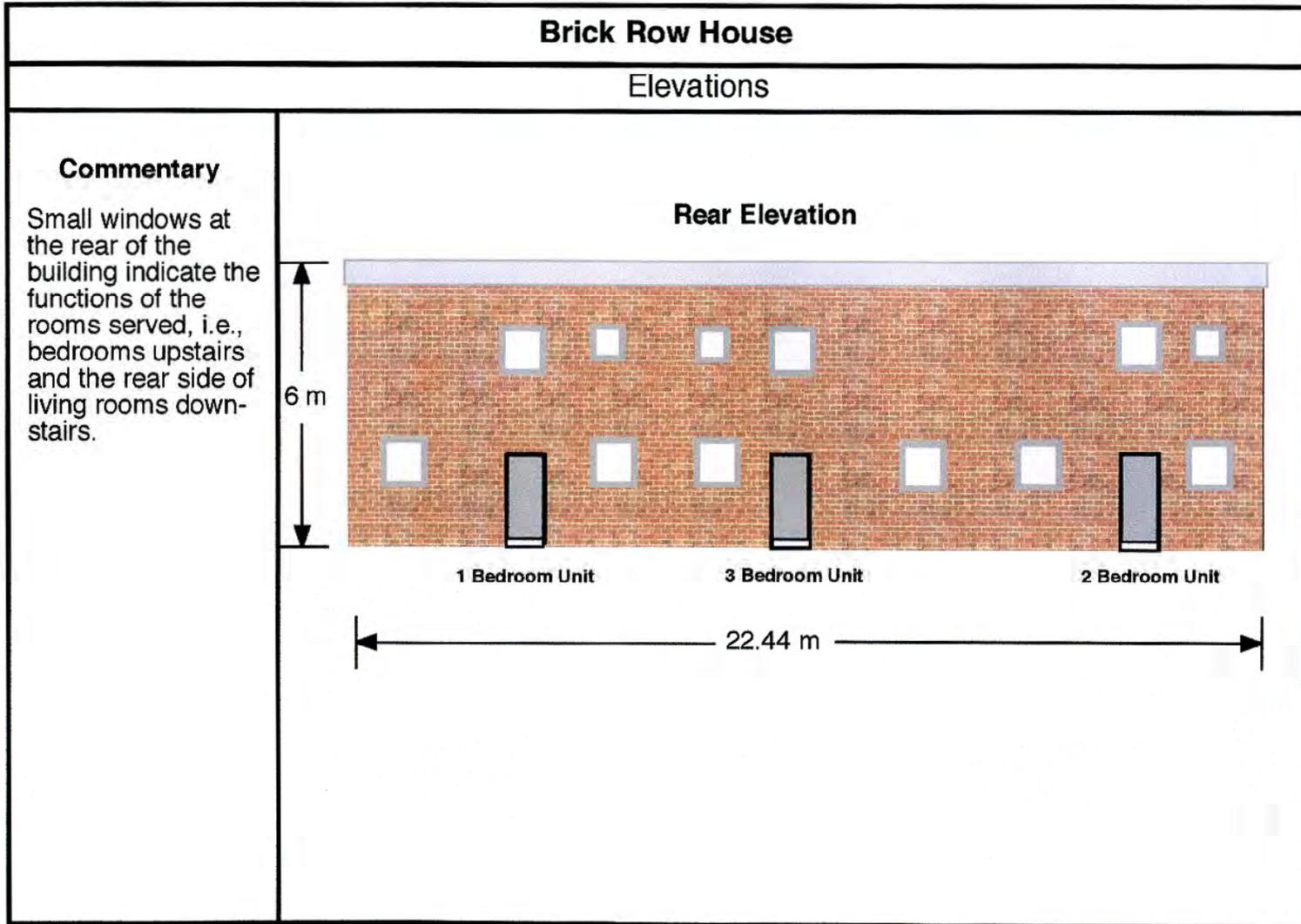


Figure 67. Mass 7-2-b elevation.

Mass 7-3-a Floor Plan

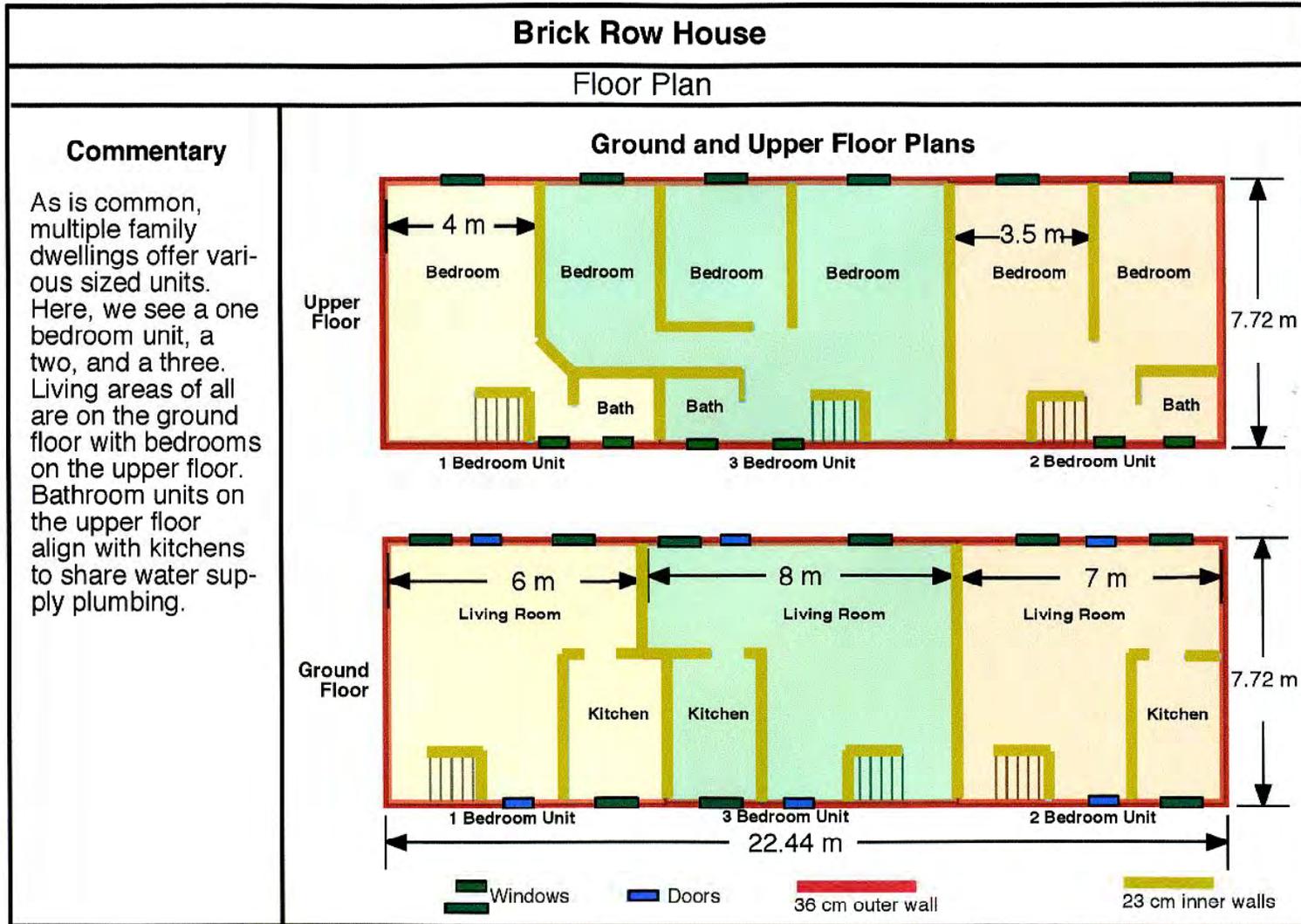


Figure 68. Mass 7-3-a floor plan.

Mass 7-3-b Isometric Floor Plan

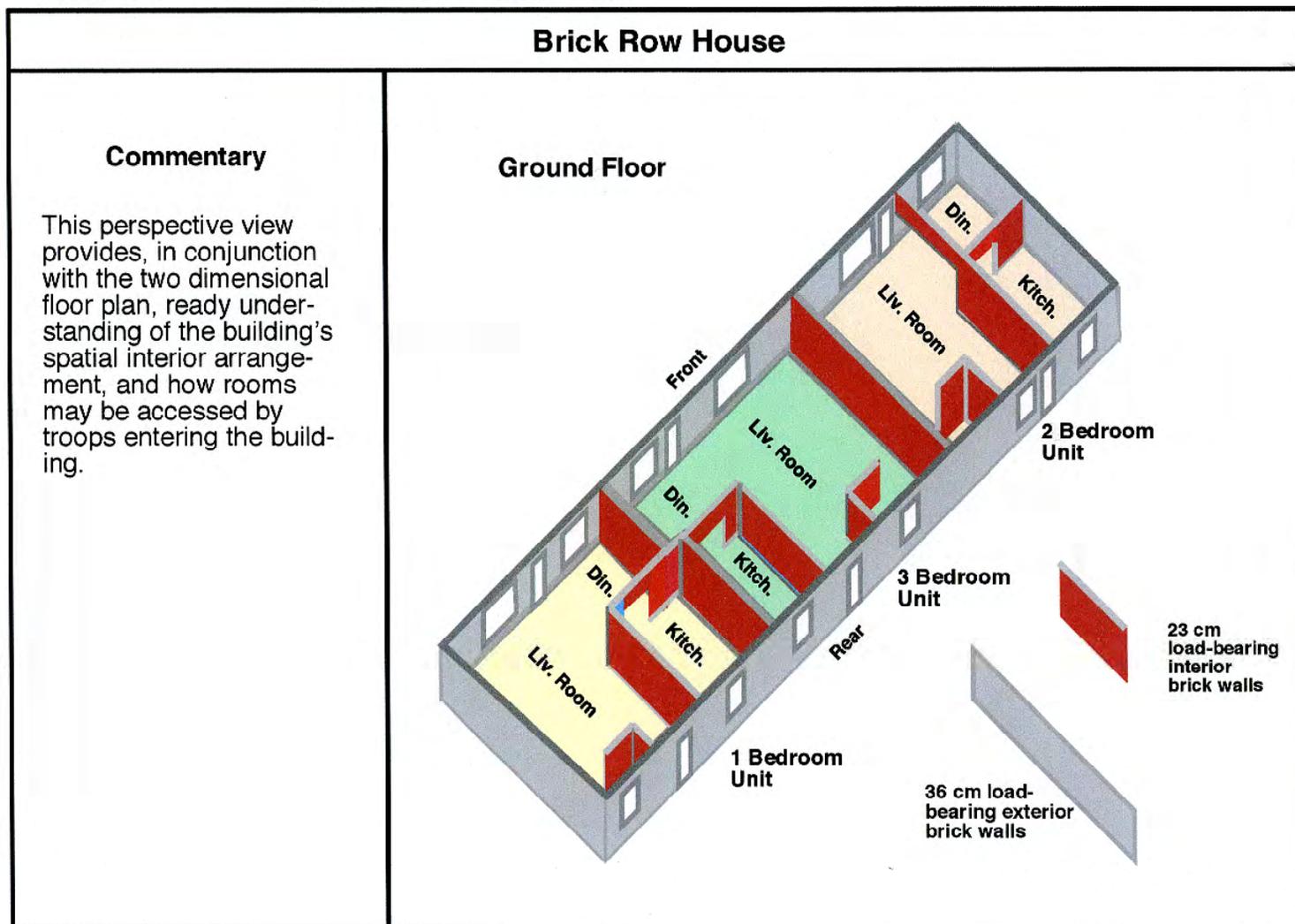


Figure 69. Mass 7-3-b floor plan.

Mass 7-3-c Isometric Floor Plan

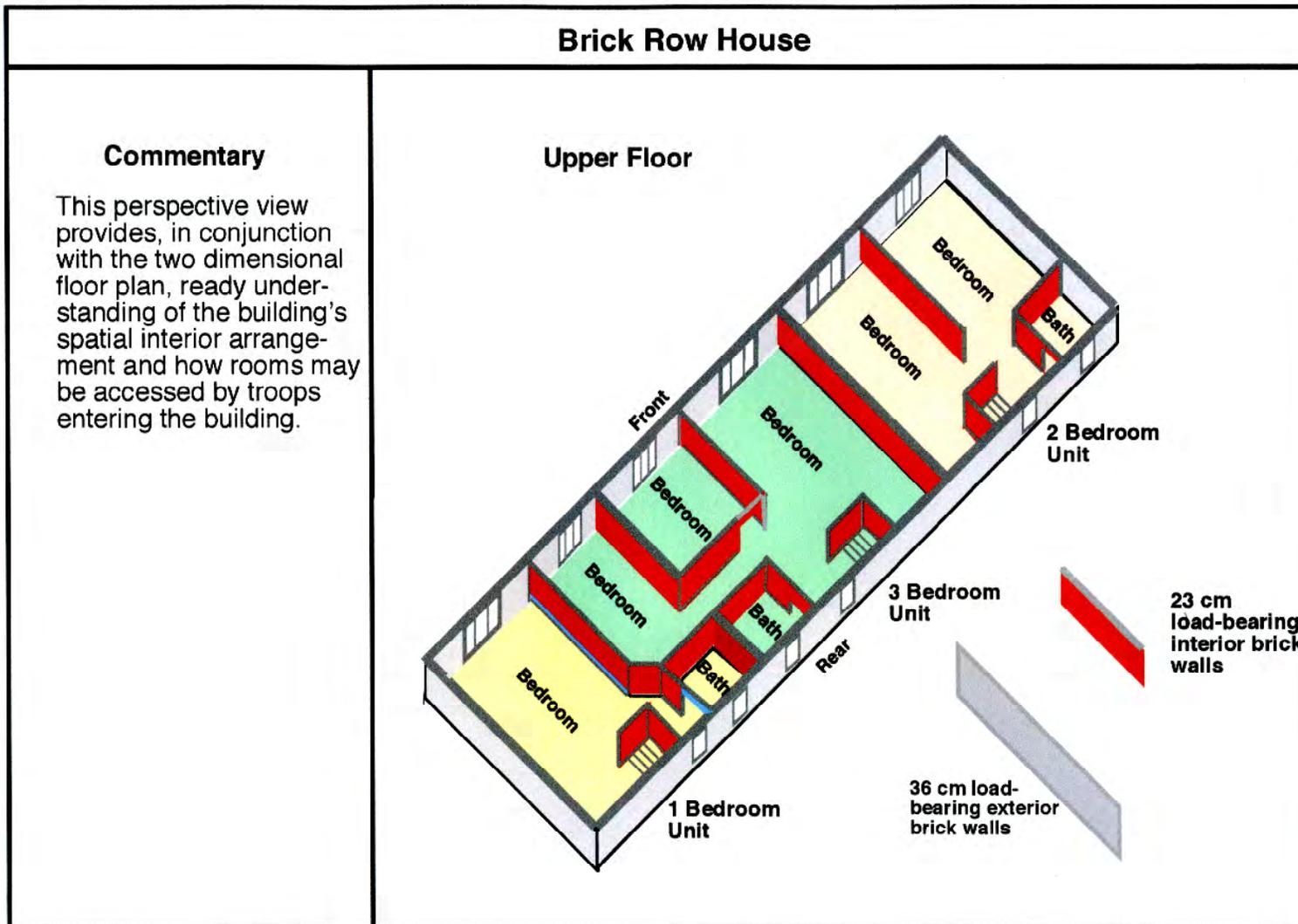


Figure 70. Mass 7-3-c isometric floor plan.

Mass 7-4 Construction

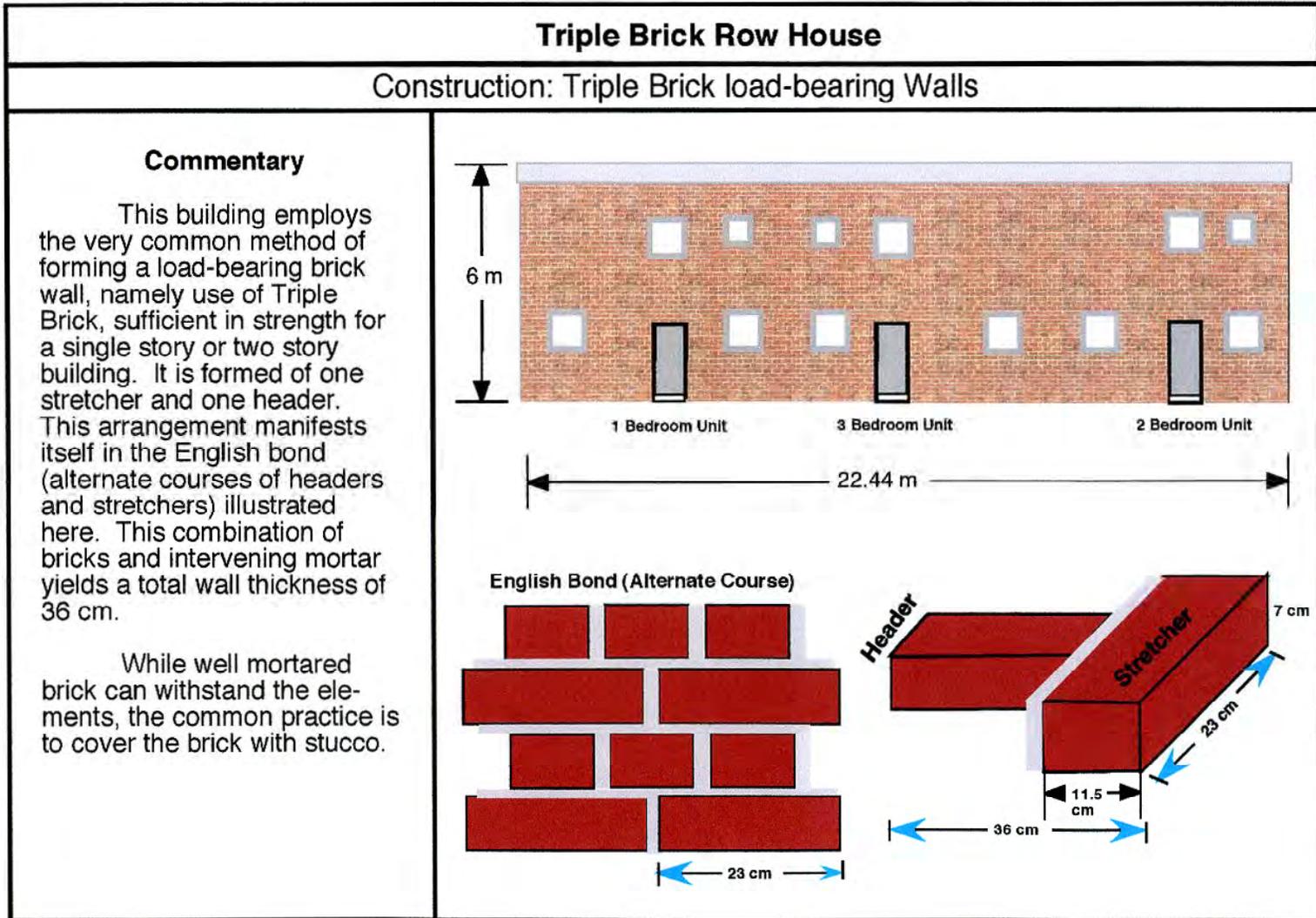
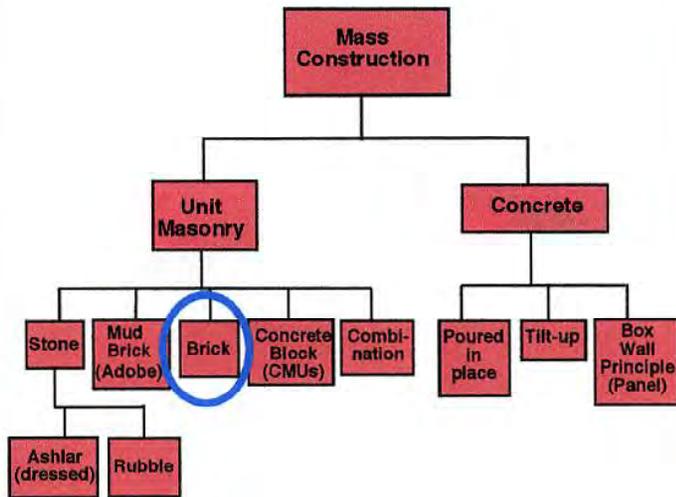


Figure 71. Mass 7-4 construction.

Mass 8-1 Place on Building Construction Chart

Brick Apartment Building, Stores Below

Place on Building Construction Chart



International Example



RE photo 2004

This elaborate, ornamented example (in Budapest, 2004) exemplifies the common features of such structures: the 1 x 1.5 meter windows of the upper floor are aligned (to keep minimal the loss of support in a brick building); the ground floor windows are larger to allow for display of retail goods. Styling is traditional with pediment on the ground floor, the shaft containing the apartments, and a decorative capital.

World locations where Brick Buildings are important

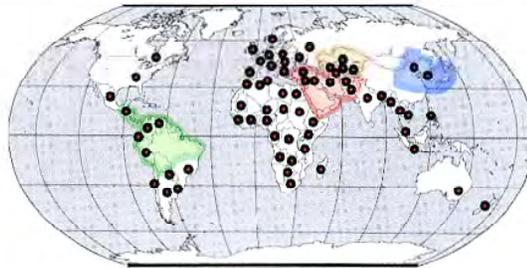


Figure 72. Mass 8-1 place on building construction chart.

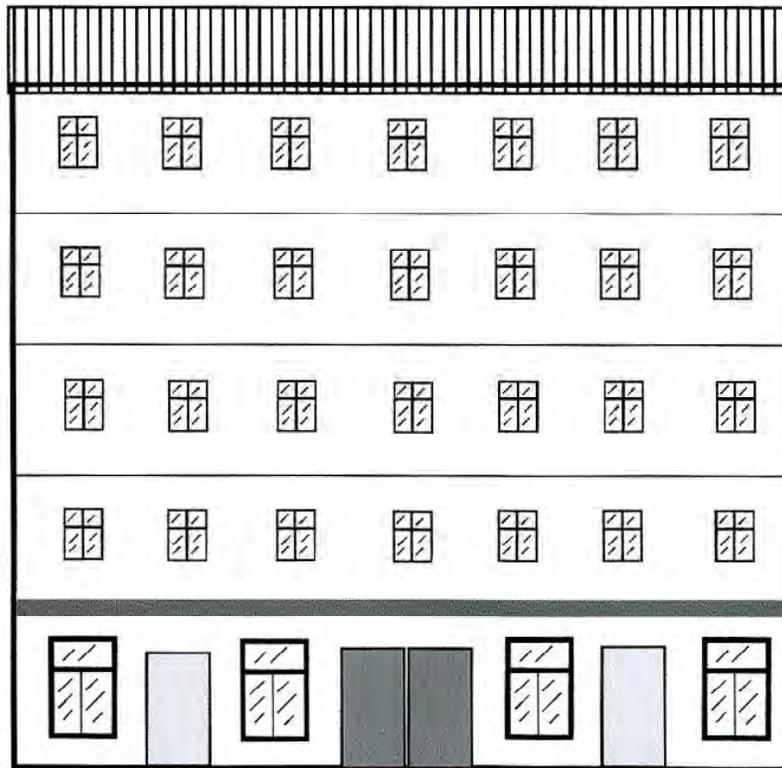
Mass 8-2 Elevation

Brick Apartment Building, Stores Below

Front Elevation and Wall Thickness

Commentary

This building is archetypical of countless numbers seen in large European cities. Brick was used in their construction as it was the only possible means of constructing multi-story buildings prior to the end of the 19th century (and coinciding with a period of imperialism when demand for large buildings was great). Five stories was the practical limit before the advent of elevators. The use of brick meant that walls on the lower floors had to be very strong, which meant greater thickness of brick, to support the load above. Ground floor walls were commonly about 1 meter thick (8 bricks = 96 cm). As each building was constructed independently, adjacent buildings also abided by the thickness rules, thus yielding ground floor combined walls almost 2 meters thick.

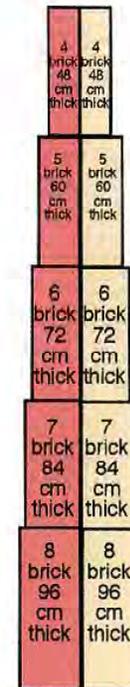


Retail Shop

Entry Door
to Hof

Retail Shop

27.42 m



Wall Thickness
Shown Building
and Adjacent
Similar Building

Figure 73. Mass 8-2 elevation.

Mass 8-3-a Floor Plan

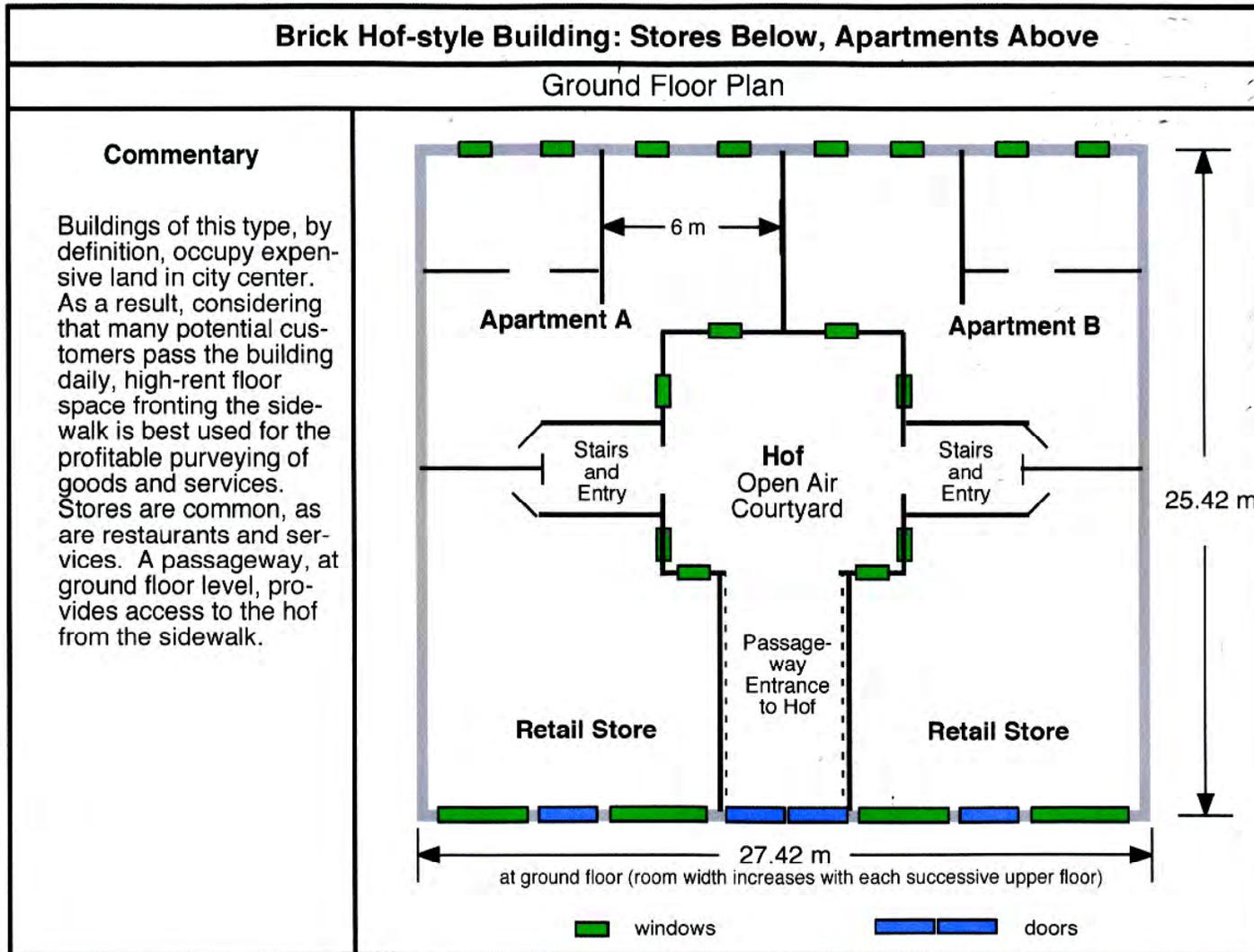


Figure 74. Mass 8-3-a floor plan.

Mass 8-3-b Floor Plan

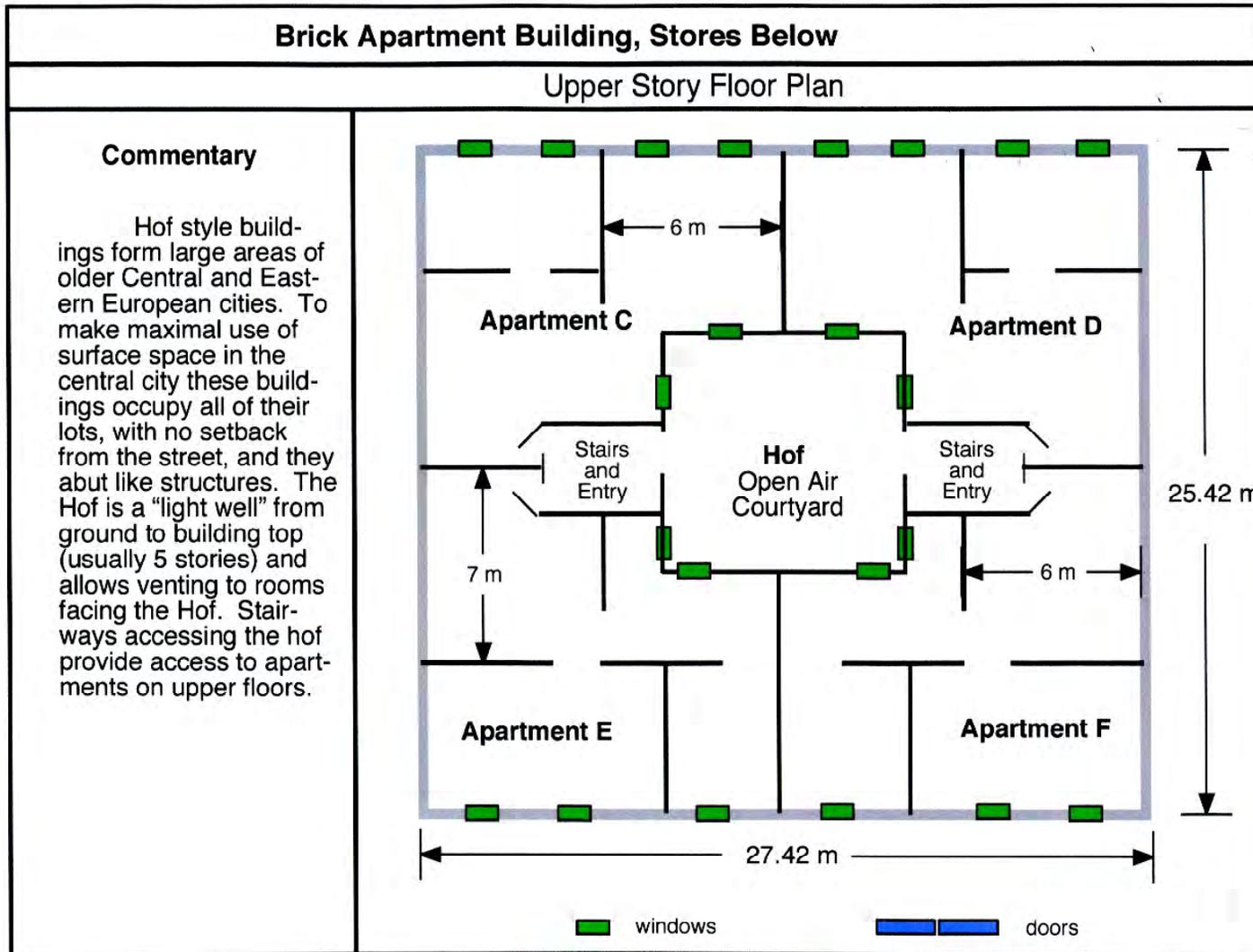


Figure 75. Mass 8-3-b floor plan.

Mass 8-4 Construction

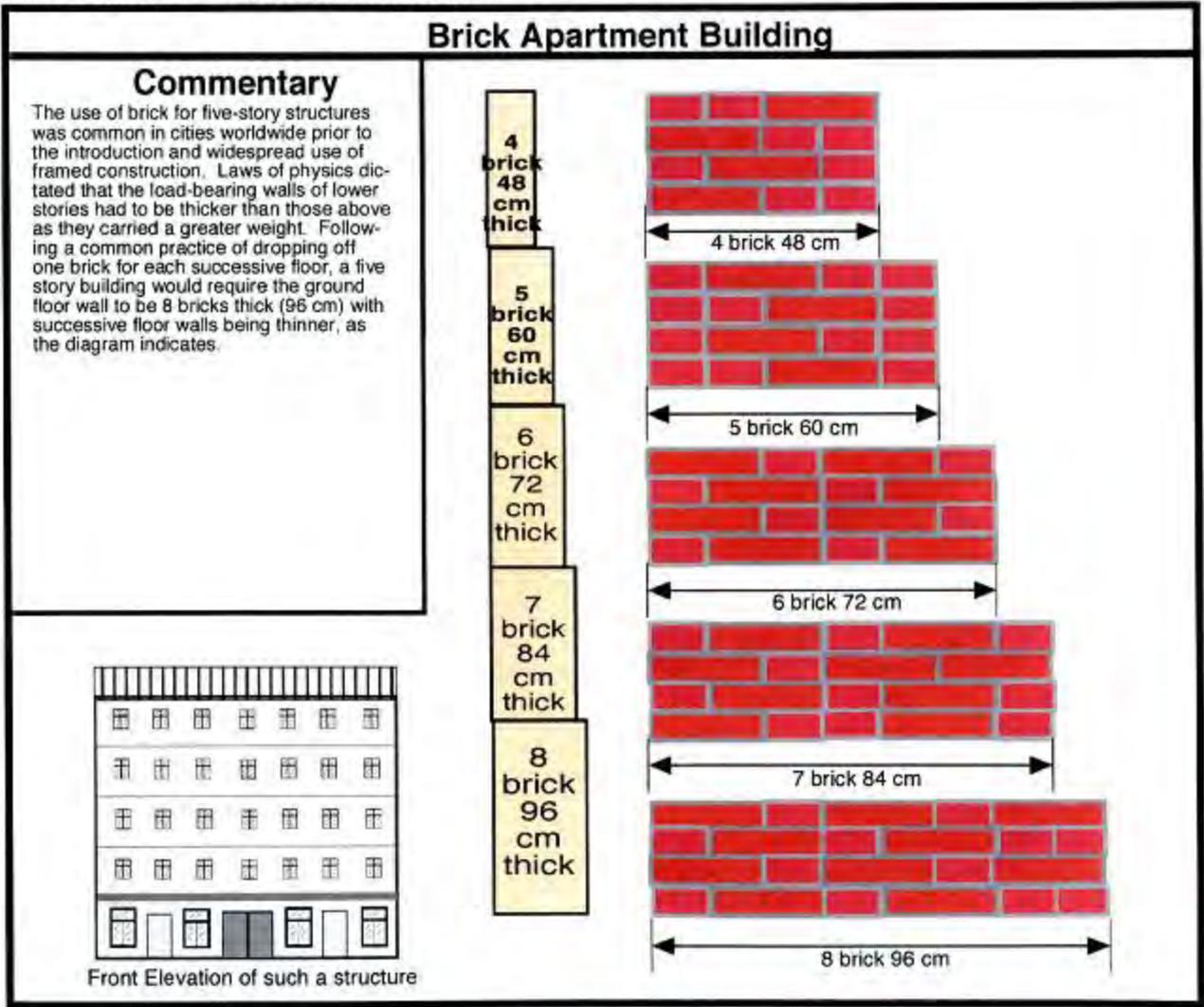


Figure 76. Mass 8-4 construction.

Mass 9-1 Place on Building Construction Chart

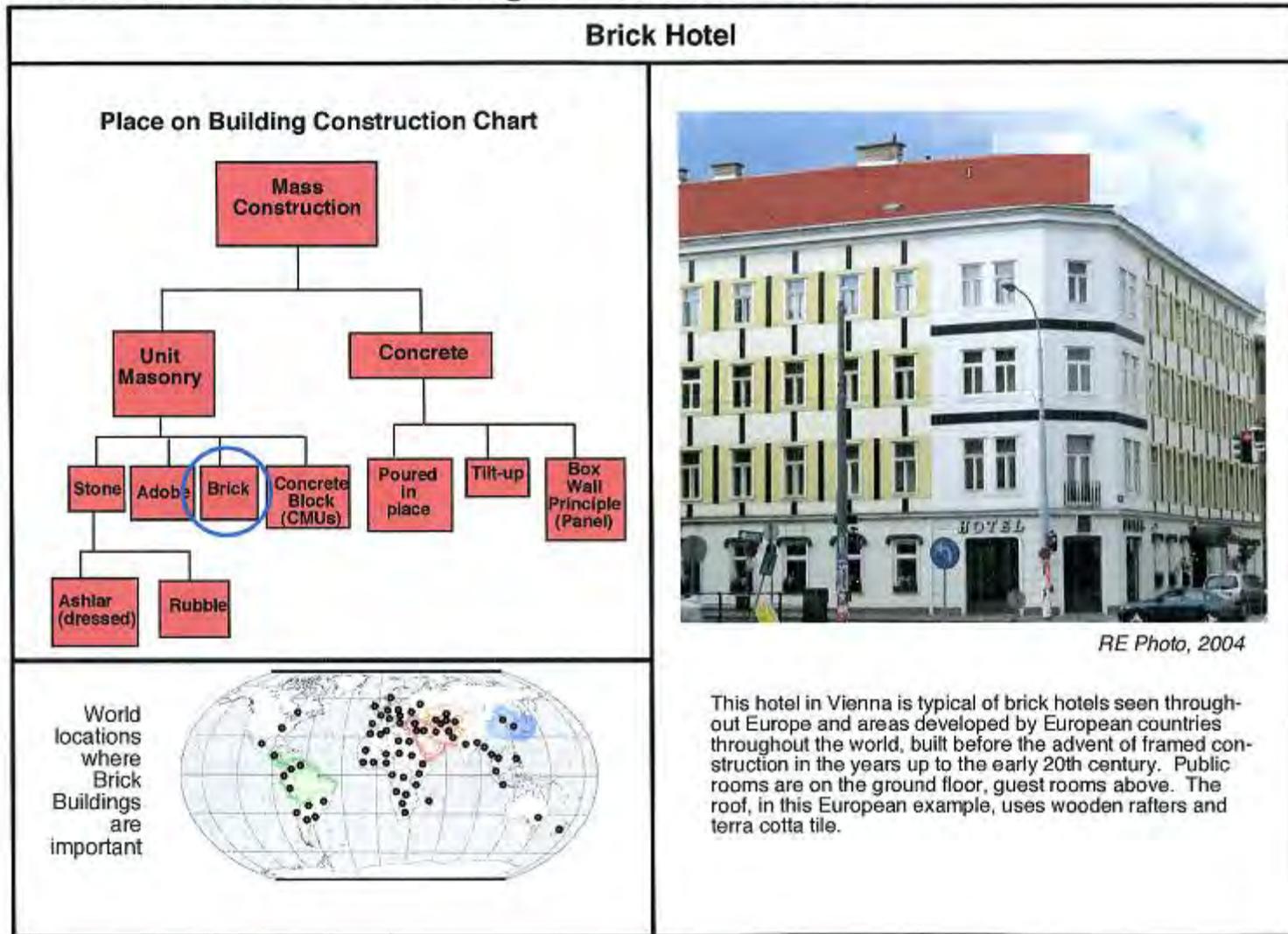


Figure 77. Mass 9-1 place on building construction chart.

Mass 9-2 Elevation

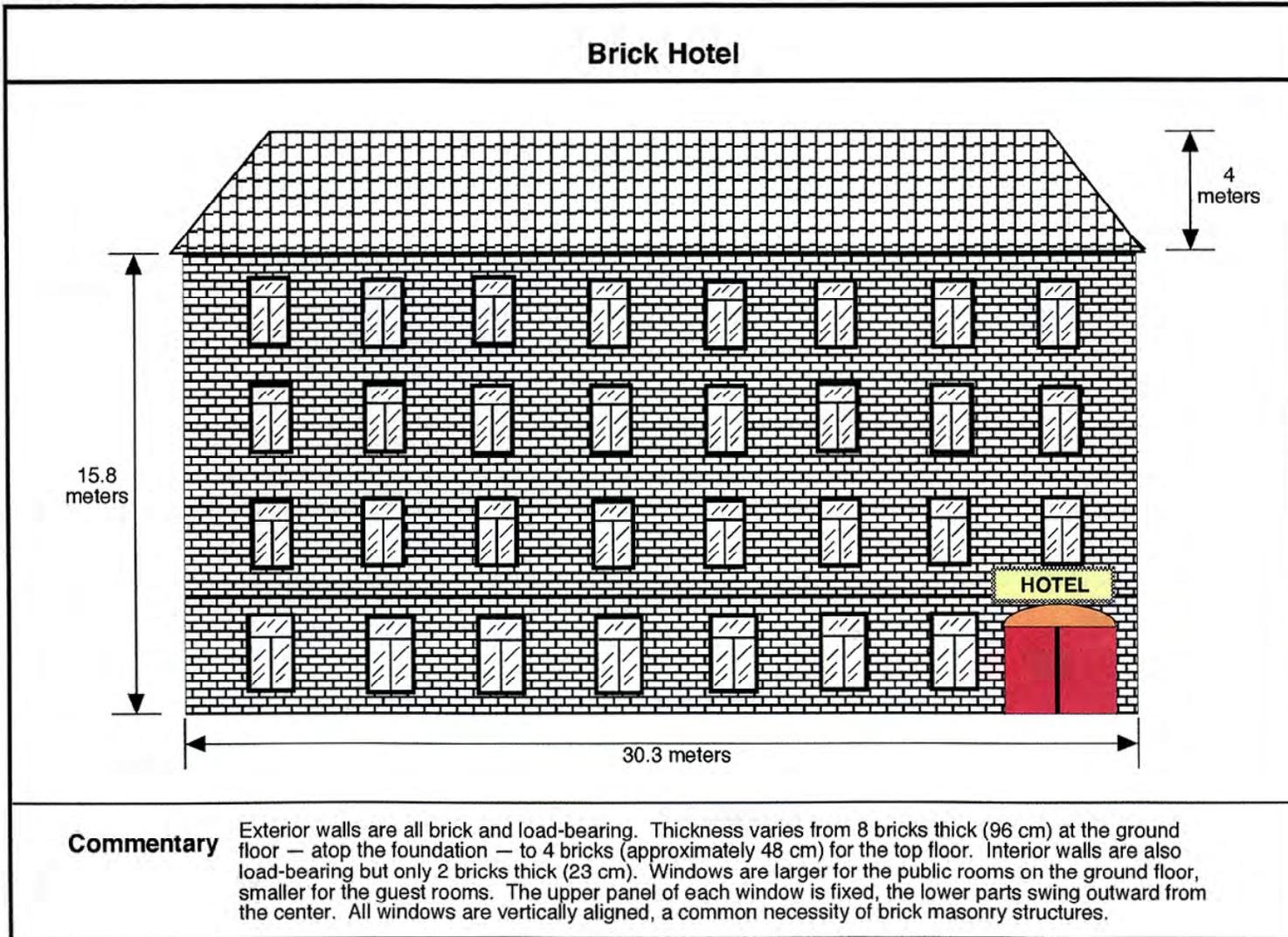


Figure 78. Mass 9-2 elevation.

Mass 9-3-a Floor Plans

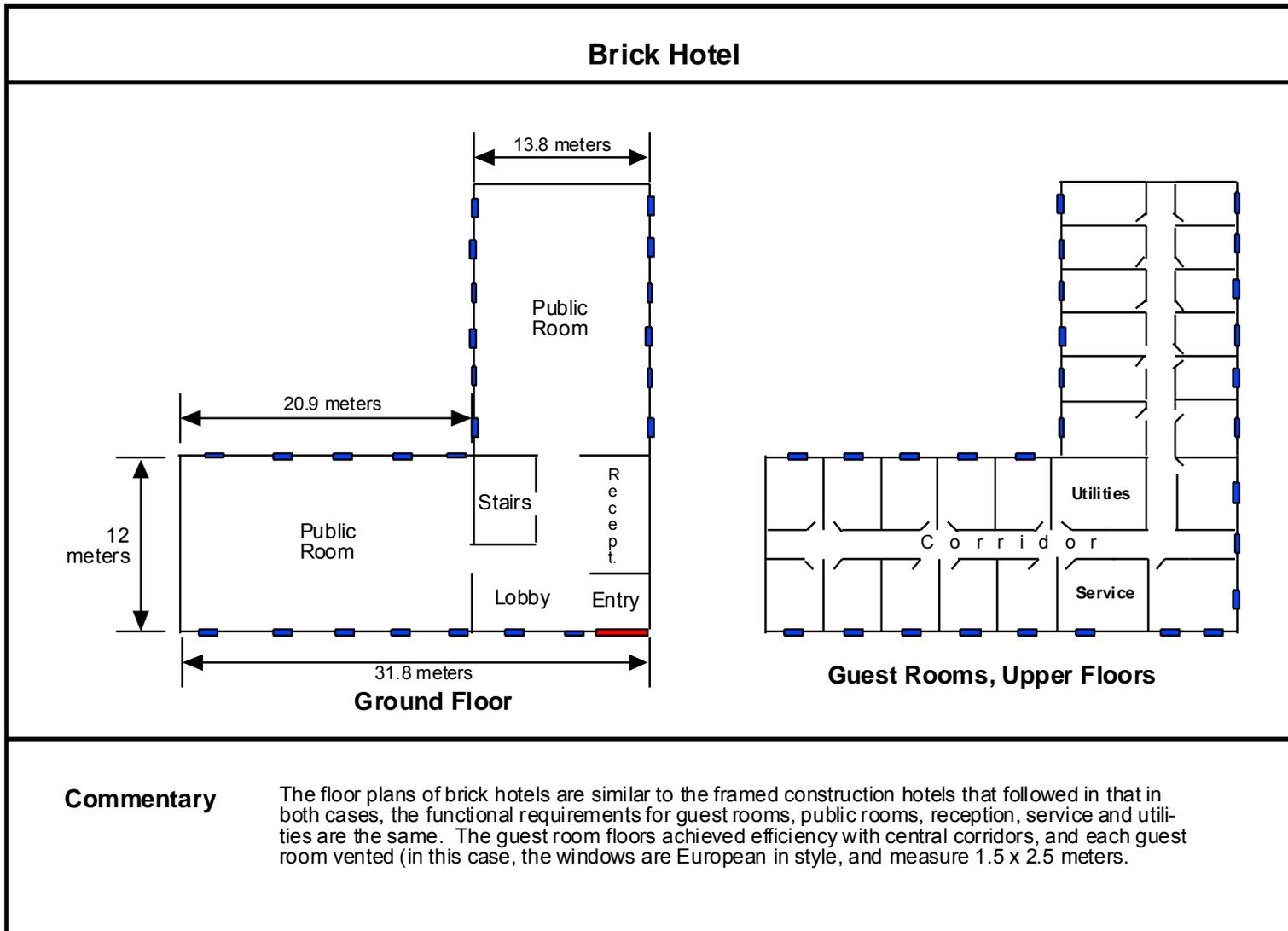


Figure 79. Mass 9-3-a floor plans.

Mass 9-4 Construction: Wall and Window

Brick Apartment Building, Stores Below

Wall Thickness of Brick Building, Measured at Windows at Ground and Fifth Floor



Wall thickness at Ground Floor: 96 cm (8 bricks)



Window at Fourth Floor: 1.5 meters high, 1 meter wide



Wall thickness at Fourth Floor: 48 cm (4 bricks)

RE Photos

The photos demonstrate how tall, mass, brick buildings must have very thick walls on the ground floor to support all loads above and have walls that get progressively thinner with each story upward. The ground floor wall is almost a full meter thick, the fourth floor close to half a meter.

Figure 80. Mass 9-4 construction: wall and window.

Mass 10-1 Place on Building Construction Chart

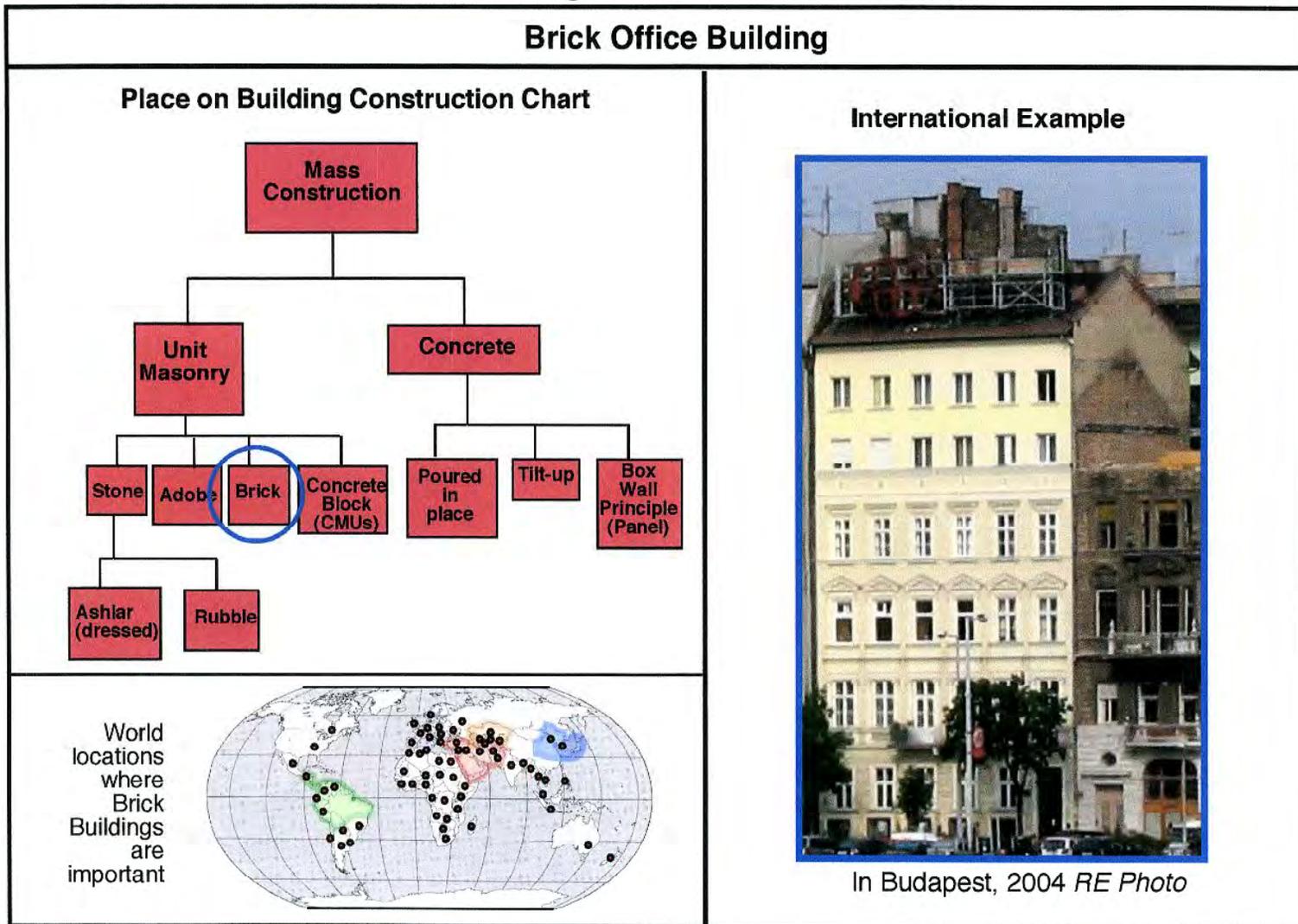


Figure 81. Mass 10-1 place on building construction chart.

Mass 10-2 Elevation

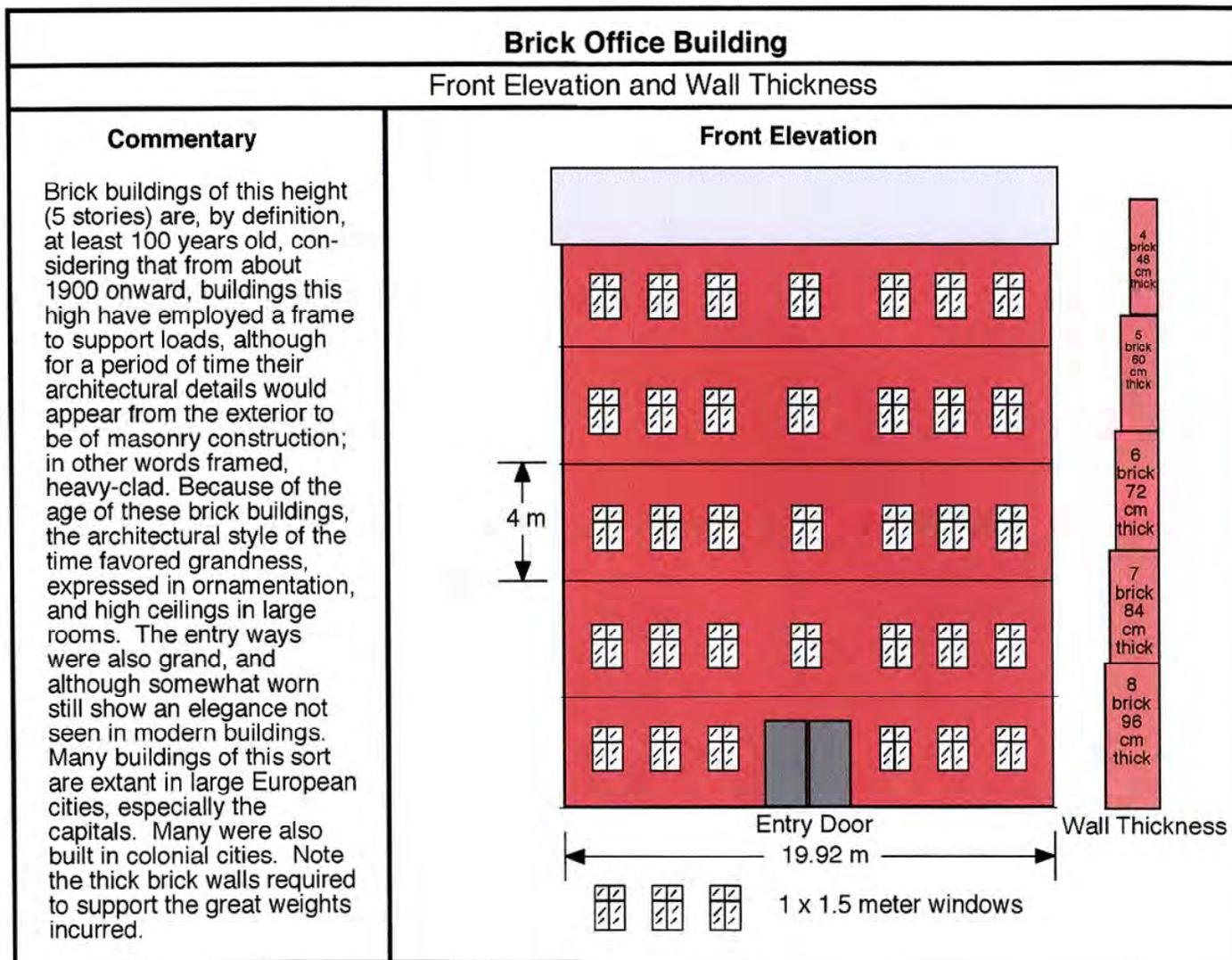


Figure 82. Mass 10-2 elevation.

Mass 10-3-a Floor Plan

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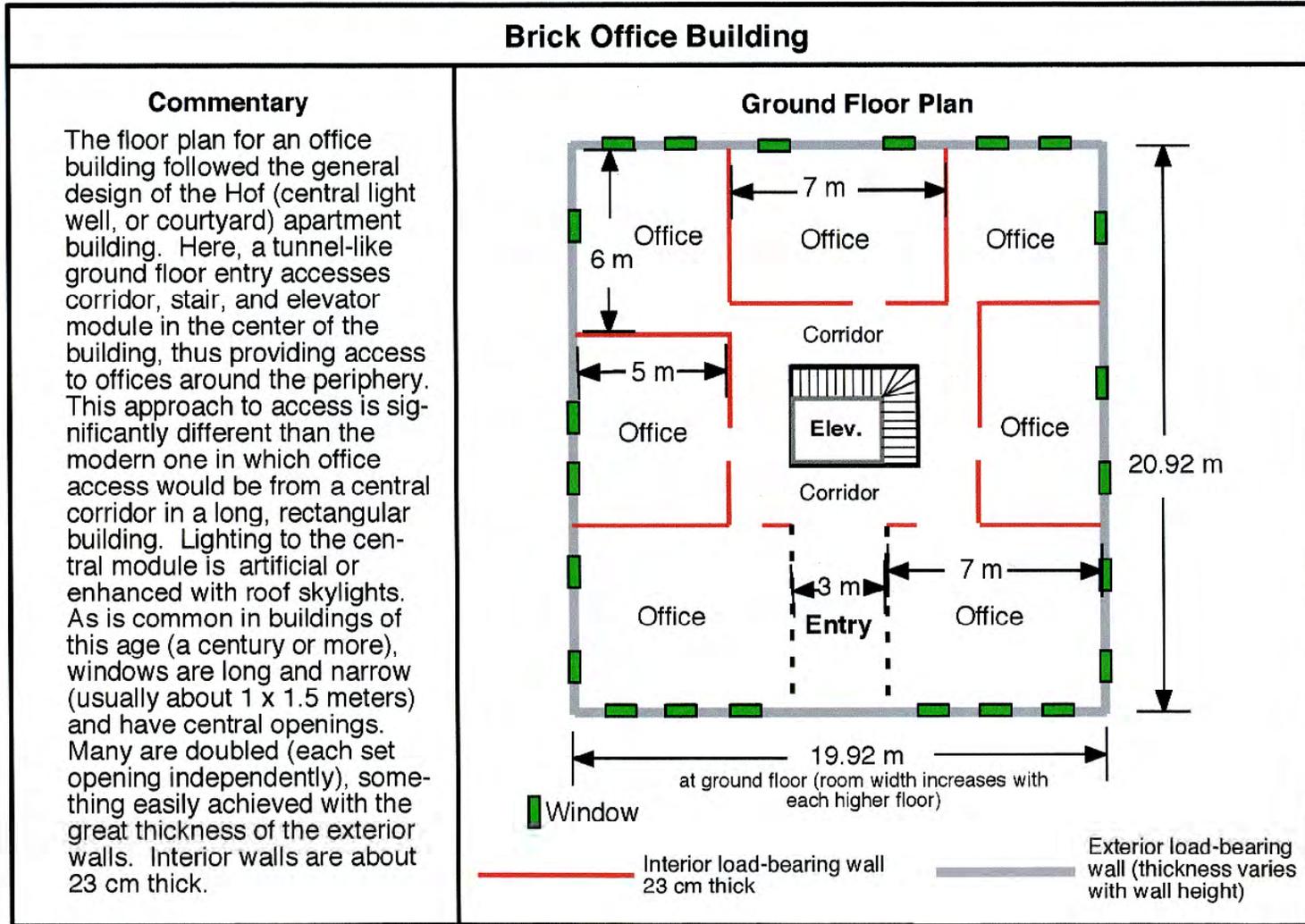


Figure 83. Mass 10-3-a floor plan.

Mass 10-3-b Floor Plan

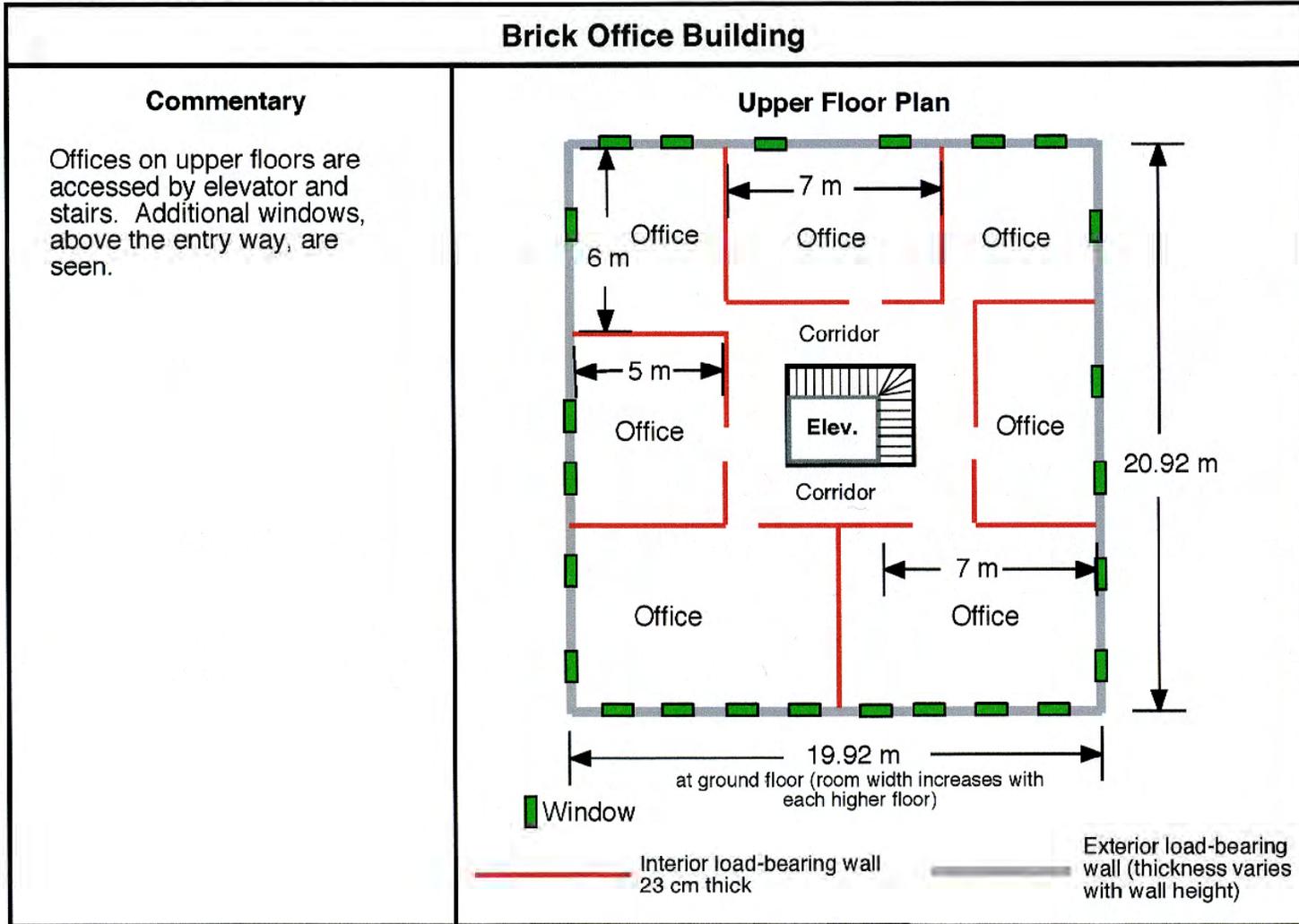
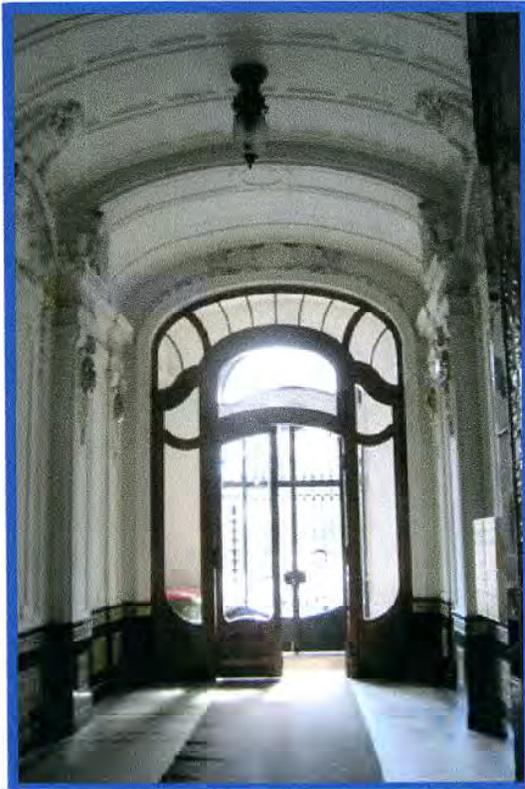


Figure 84. Mass 10-3-b floor plan.

Mass 10-4 Construction, Interiors

Brick Office Building

Entry, Stairway and Elevator



RE photo 2004



RE photo 2004

Commentary

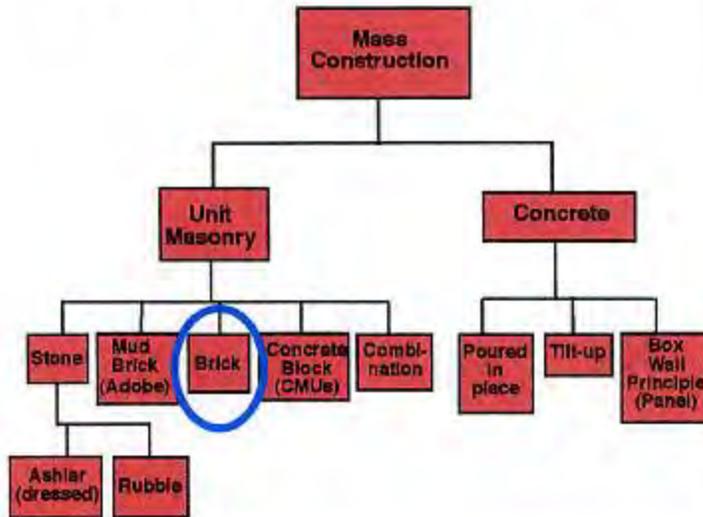
Design of these buildings (this one in Vienna) required a long entry way to the center of the building, the location of the elevator and stairs. Photo on the left, looking outward to the street entrance, demonstrates the commonly seen grand ornamentation. The photo above shows an elaborate door entrance to an office, the Victorian style elevator cage, and the decorated stair handrail.

Figure 85. Mass 10-4 construction, interiors.

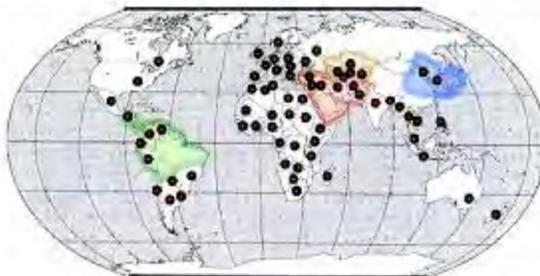
Mass 11-1 Place on Building Construction Chart

Brick Store

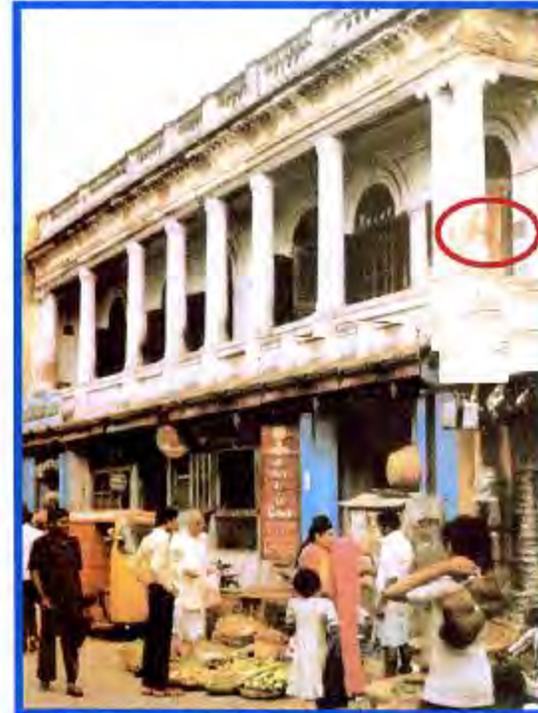
Place on Building Construction Chart



World locations where Brick Buildings are important



International Example



An elaborate brick building in Chennai (Madras), India with commercial use on the ground floor, residential above. Note exposed brick on the upper right corner. *RE photo.*

Figure 86. Mass 11-1 place on building construction chart.

Mass 11-2 Elevation

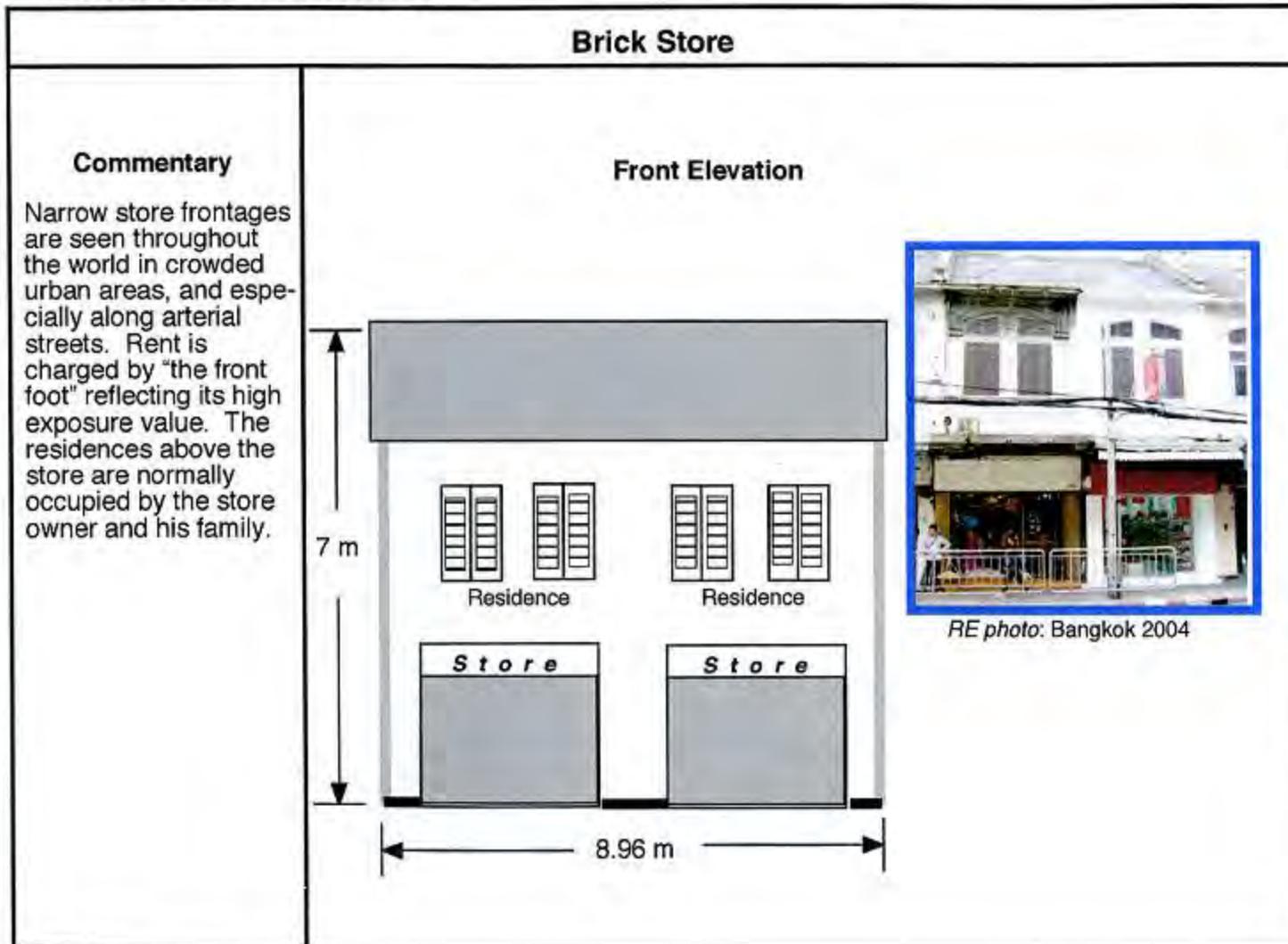


Figure 87. Mass 11-2 elevation.

Mass 11-3-a Floor Plan

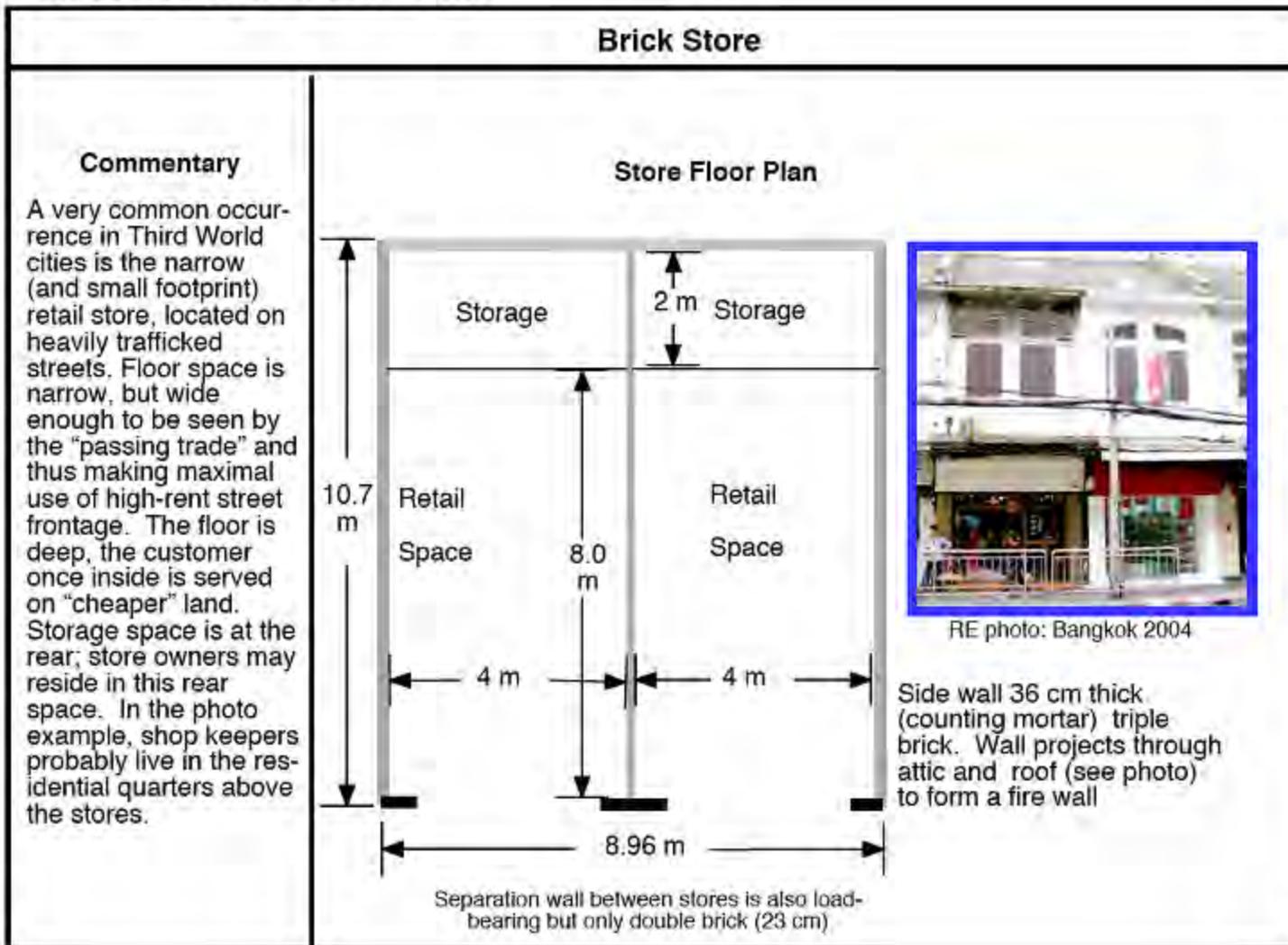


Figure 88. Mass 11-3-a floor plan.

Mass 11-4 Construction

Triple Brick Store

Construction: Triple Brick load-bearing Walls

Commentary

This building employs the very common method of forming a load-bearing brick wall, namely use of Triple Brick, sufficient in strength for a single story or two story building. It is formed of one stretcher and one header. This arrangement manifests itself in the English bond (alternate courses of headers and stretchers) illustrated here. This combination of bricks and intervening mortar yields a total wall thickness of 36 cm.

While well mortared brick can withstand the elements, the common practice is to cover the brick with stucco.

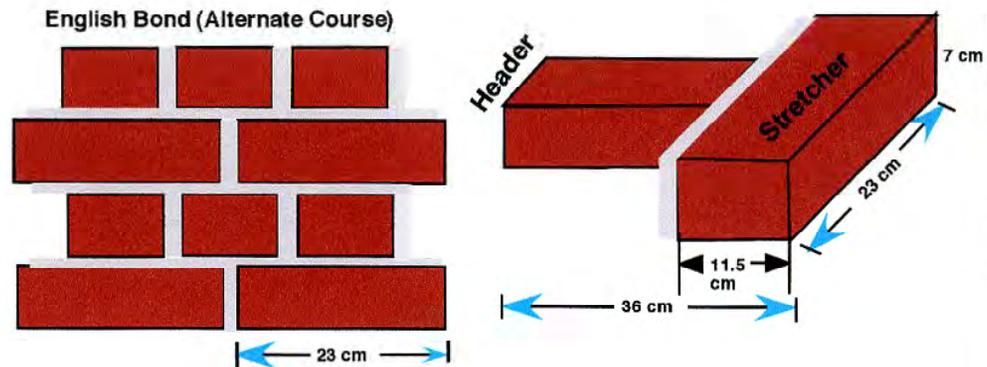
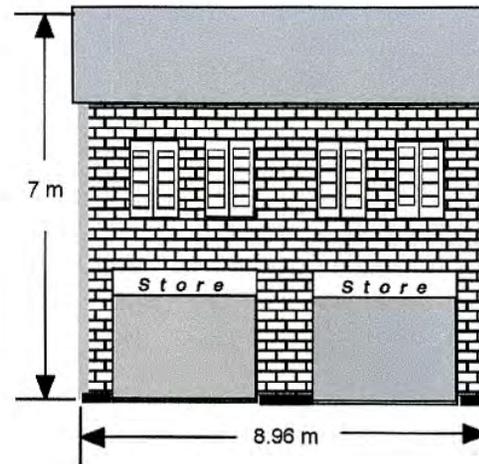
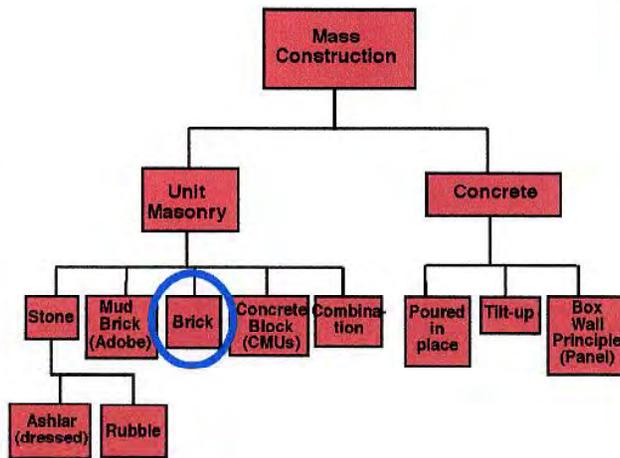


Figure 89. Mass 11-4 construction.

Mass 12-1 Place on Building Construction Chart

Brick Mosque

Place on Building Construction Chart

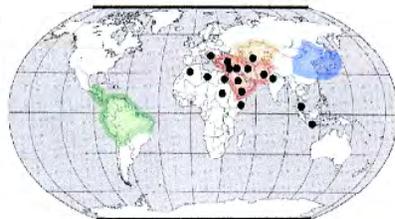


International Example



RE photo.

World locations where mosques are important



A mosque in Delhi, shows the elaborate architecture of a large mosque, used for congregational services on Fridays. This particular structure is made of the red sandstone, prominent in the Red Fort, nearby. The building has the domes, the arches, massive gateway, and the minarets (as seen in the drawings).

Figure 90. Mass 12-1 place on building construction chart.

Mass 12-2 Elevation and Floor Plan

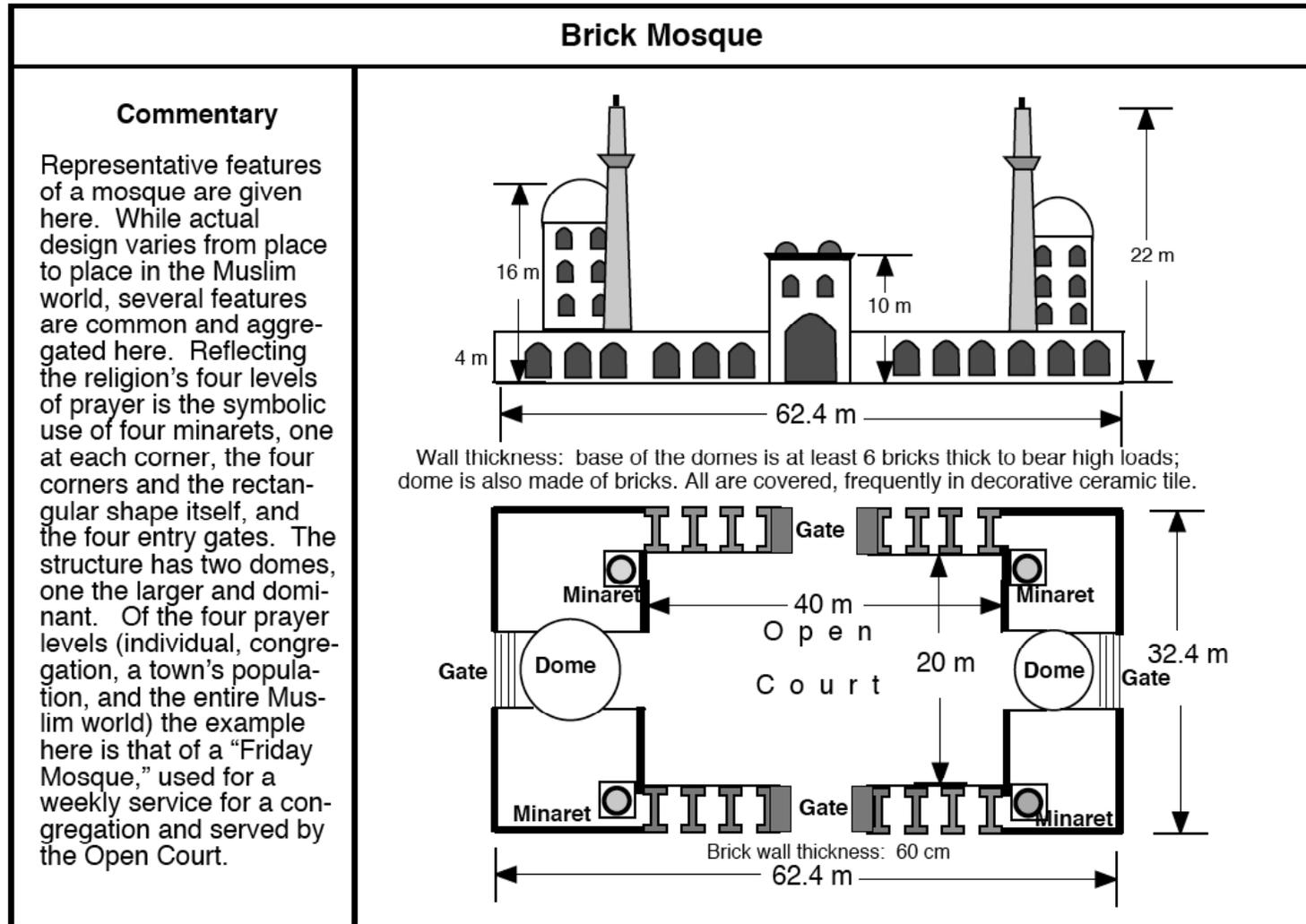


Figure 91. Mass 12-2 elevation and floor plan.

Mass 12-3-a Floor Plan

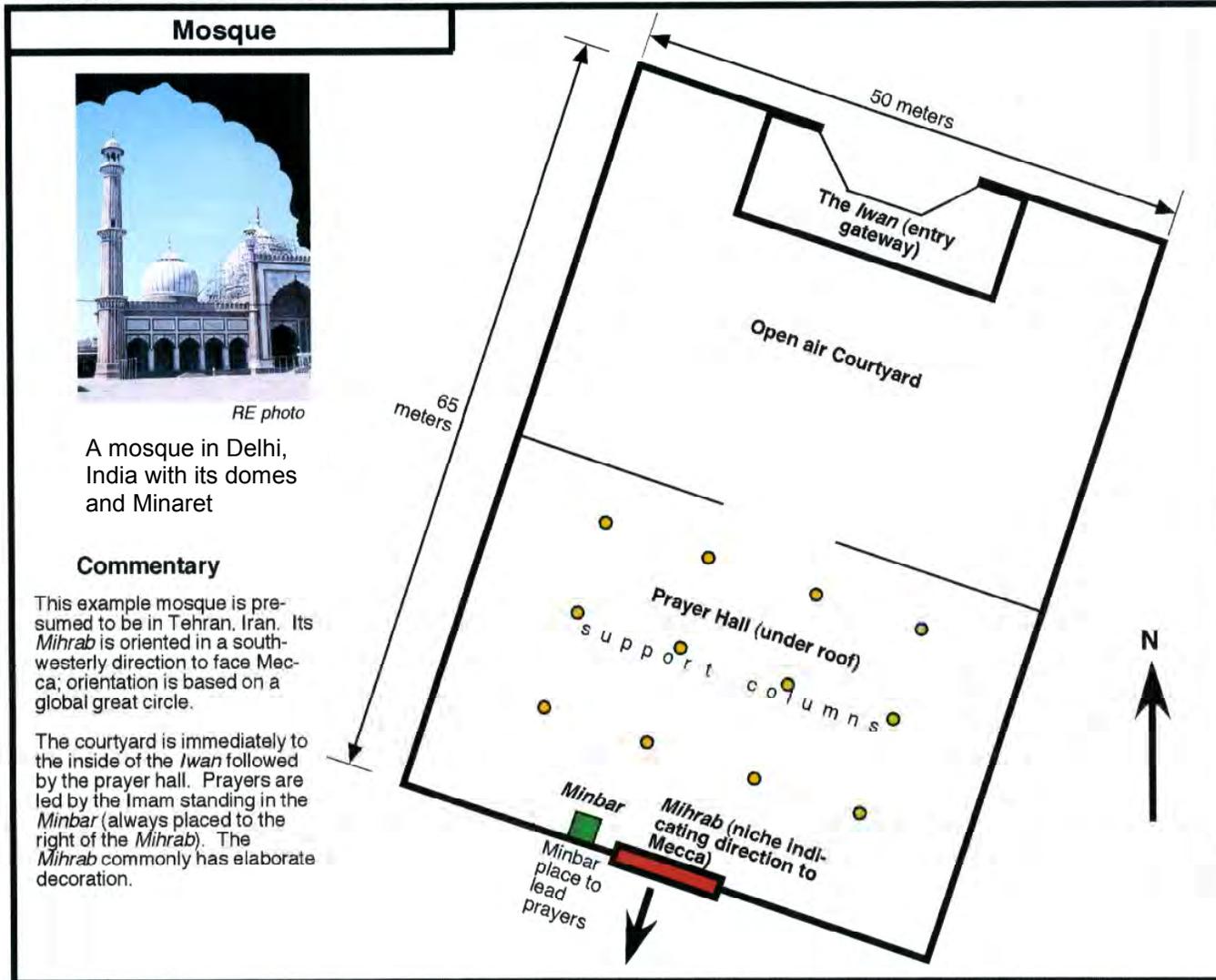


Figure 92. Mass 12-3-a floor plan.

INTENTIONALLY LEFT BLANK.

Mass 12-4 Construction

Mosque

Commentary

Considering that Islam is found in many diverse regions of the world, a variety of construction forms occur. Examples of construction here, common mainly to the Middle East, Central and Southwest Asia, employ brick and stone construction.

Selected are features basic to all mosques, i.e., the entry gateway (the *Iwan*); minarets; domes; interior columns to support the roof of the enclosed prayer room. Examples of materials and dimensions are intended to represent an average. Many variations occur due to local physical situations and to history; recently built mosques will often employ modern building techniques and materials, such as reinforced concrete.



RE photo

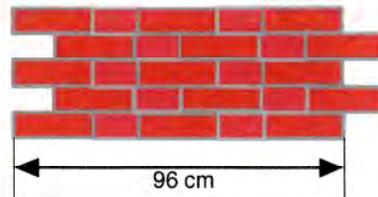
A minaret with its typical tapered form and the platforms for the call to prayer. Stairways to the top are internal.



RE photo

Domes are complex structures. They can be made of brick, stone, wood, or reinforced concrete.

Interior columns often use stacked stones. Brick and concrete are also used.



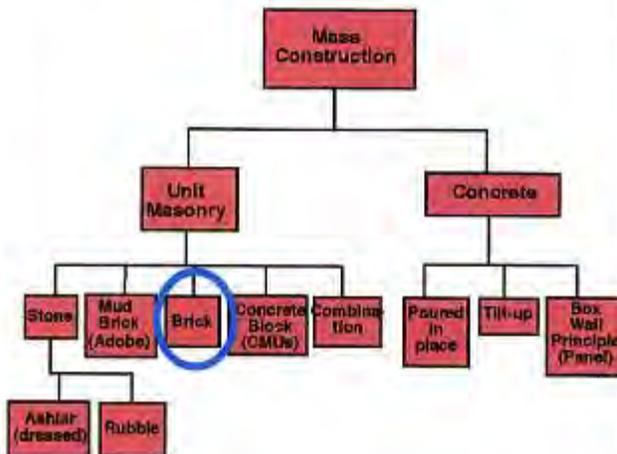
Cross-section of part of the exterior wall, 96 cm thick. The complex Flemish bond, illustrated, is commonly used in mosque construction.

Figure 93. Mass 12-4 construction.

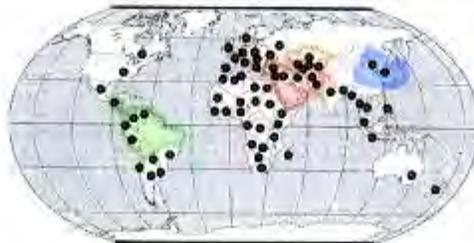
Mass 13-1 Place on Building Construction Chart

Brick Industrial/Storage Building

Place on Building Construction Chart



World locations where Brick Buildings are important



International Example



RE photo.

Prior to the advent of economical construction with reinforced concrete posts and beams with CMU, brick, or terra cotta infill, those activities needing large enclosed areas for industry or storage used traditional brick construction (triple brick, in this example case). This building is being used by a cooperative engaged in the production of "Sherry" (so derived from the name of the province of Jerez, in Spain). The arched windows at the front of the building are a good indication of its brick nature, the arches replacing load-carrying support when window openings were made.

Figure 94. Mass 13-1 place on building construction chart.

Mass 13-2 Elevation

Brick Industrial/Storage Building

Commentary

This simple brick structure has in common with its more advanced counterparts a large truck access door, window venting, and a person access door. The pitched roof is common.

Front Elevation

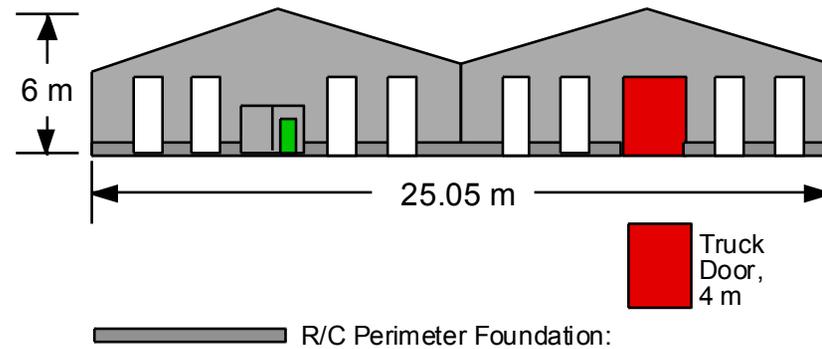


Figure 95. Mass 13-2 elevation.

Mass 13-3-a Floor Plan

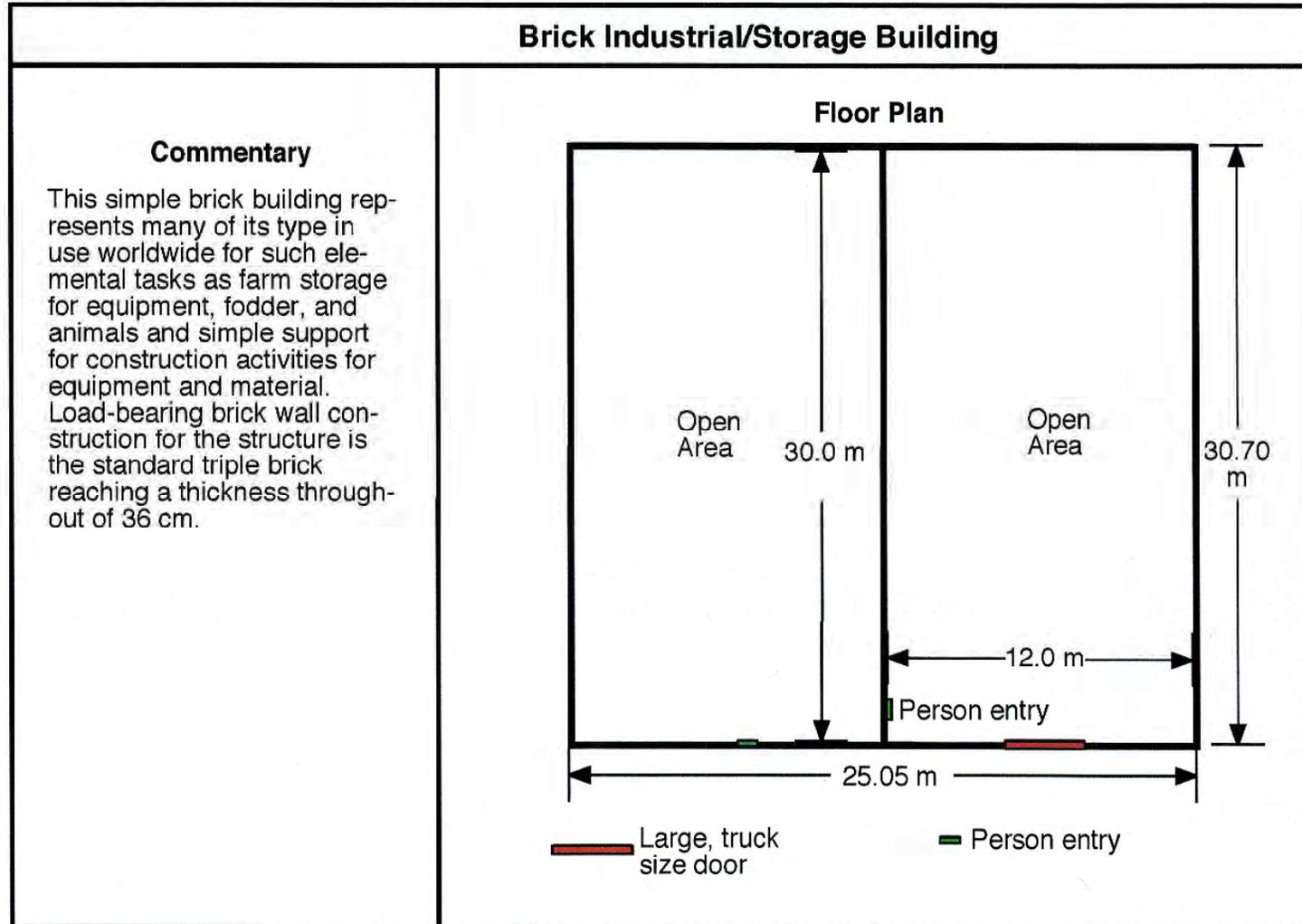


Figure 96. Mass 13-3-a floor plan.

Mass 13-4 Construction

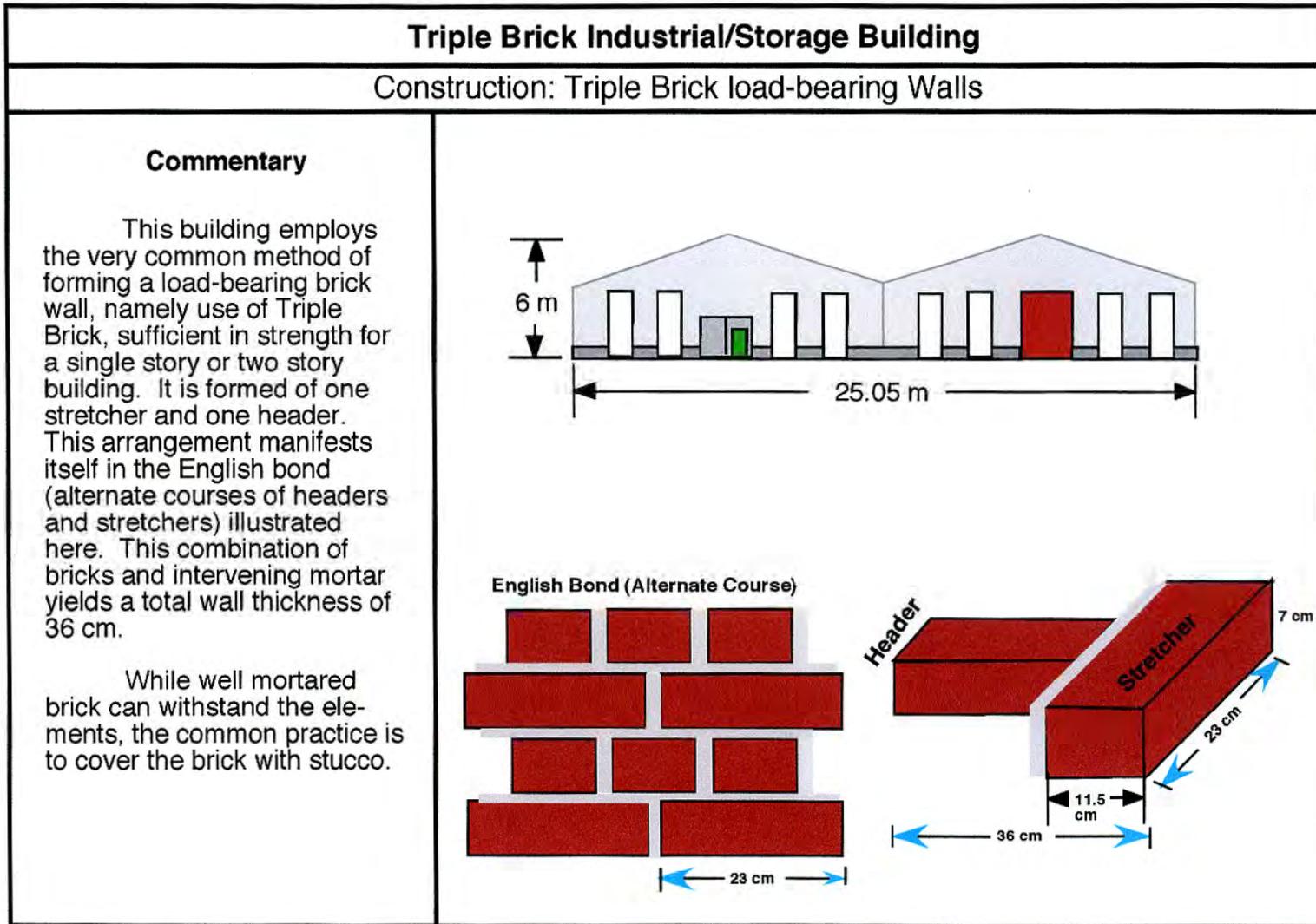


Figure 97. Mass 13-4 construction.

Mass 14-1 Place on Building Construction Chart

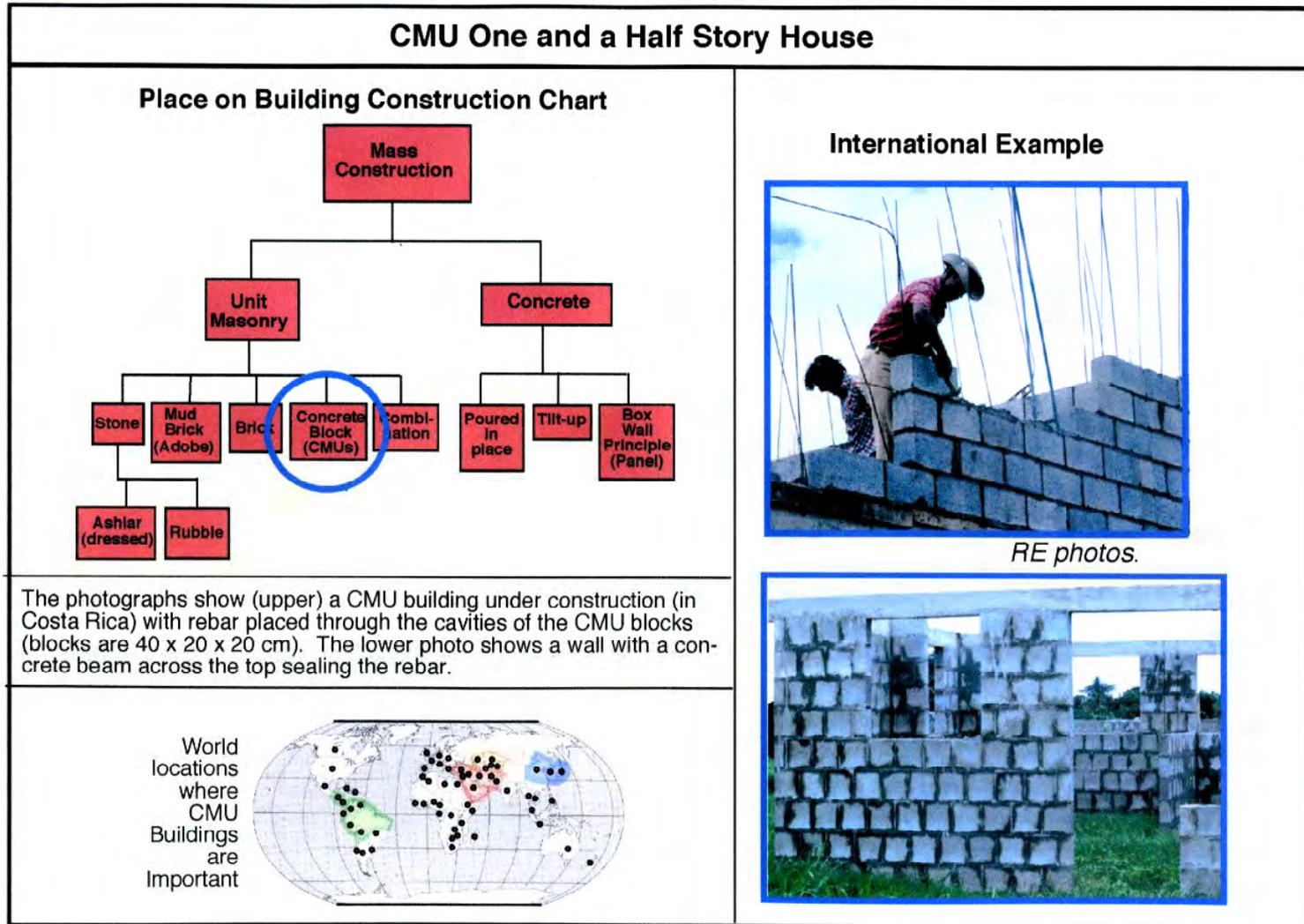


Figure 98. Mass 14-1 place on building construction chart.

Mass 14-2 Elevations

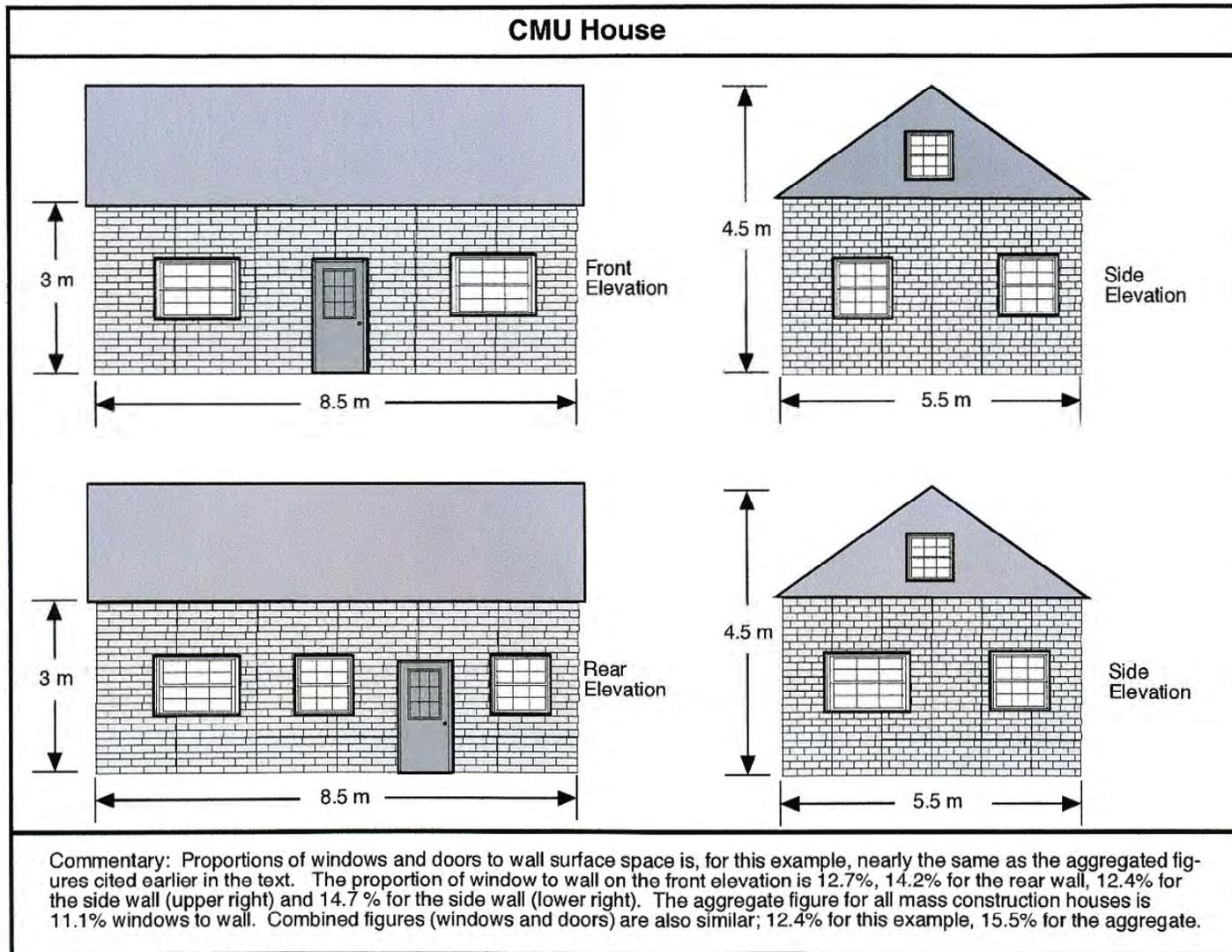


Figure 99. Mass 14-2 elevations.

Mass 14-3-a Floor Plan

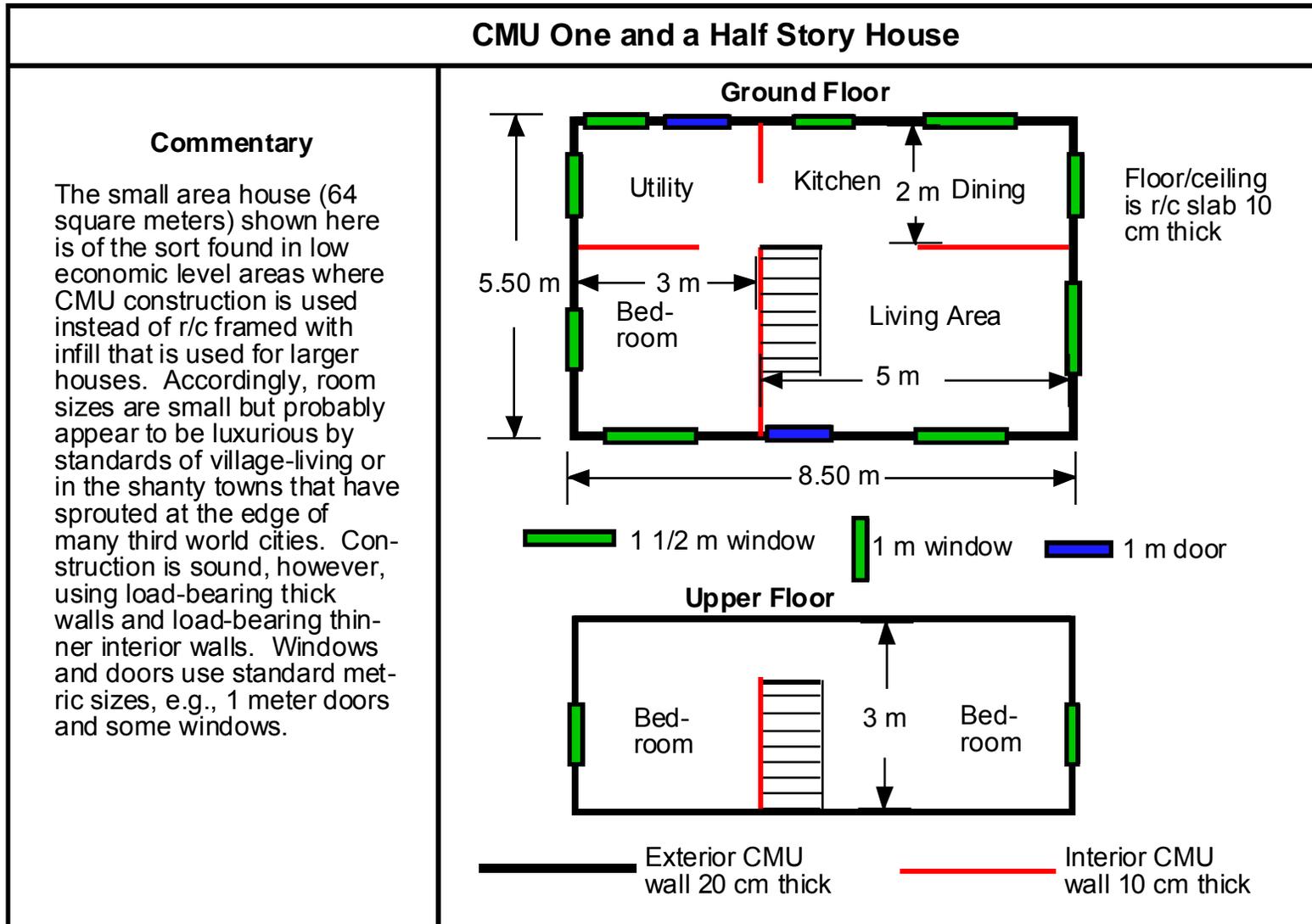


Figure 100. Mass 14-3-a floor plan.

Mass 14-4-a Construction

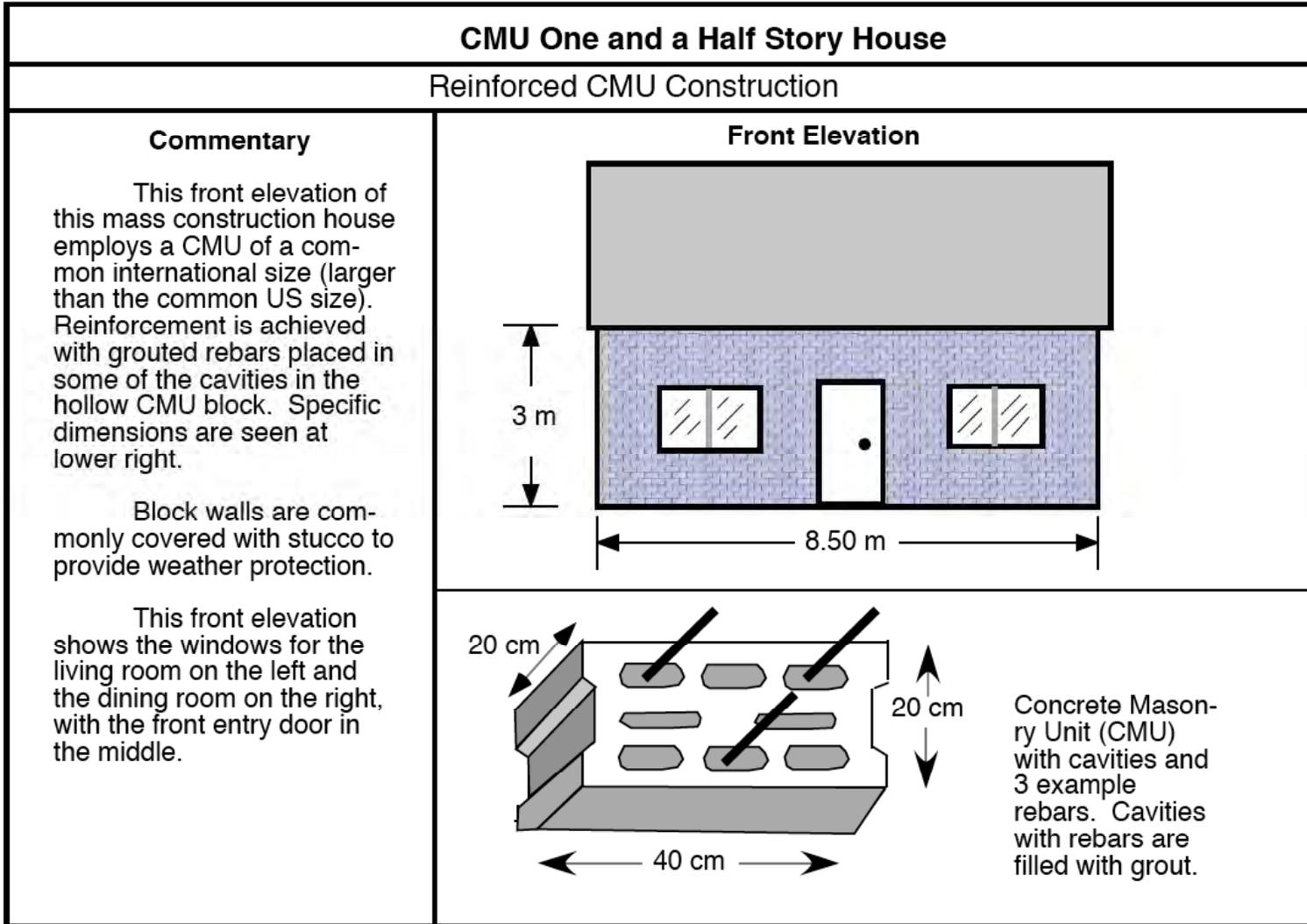


Figure 101. Mass 14-4-a construction.

Mass 14-4-b Constructon

CMU One and a Half Story House



Two cavity CMU blocks have a single rebar in each cavity. Grout has been poured and tamped as each course is added. Maximum construction here meets earthquake code in California. *RE photo.*



Another method of reinforcement uses two rebars placed in alternate cavities.



The same wall as above showing double rebar at the wall's corner. *RE photo.*

Commentary

Use of reinforcement and its density and use of grout vary from no reinforcement in simple Third World buildings and simple structures in the First World to maximum reinforcement in well capitalized construction in advanced areas, especially where code dictates and structures are built to last.

Figure 102. Mass 14-4-b construction.

Mass 15-1 Place on Building Construction Chart

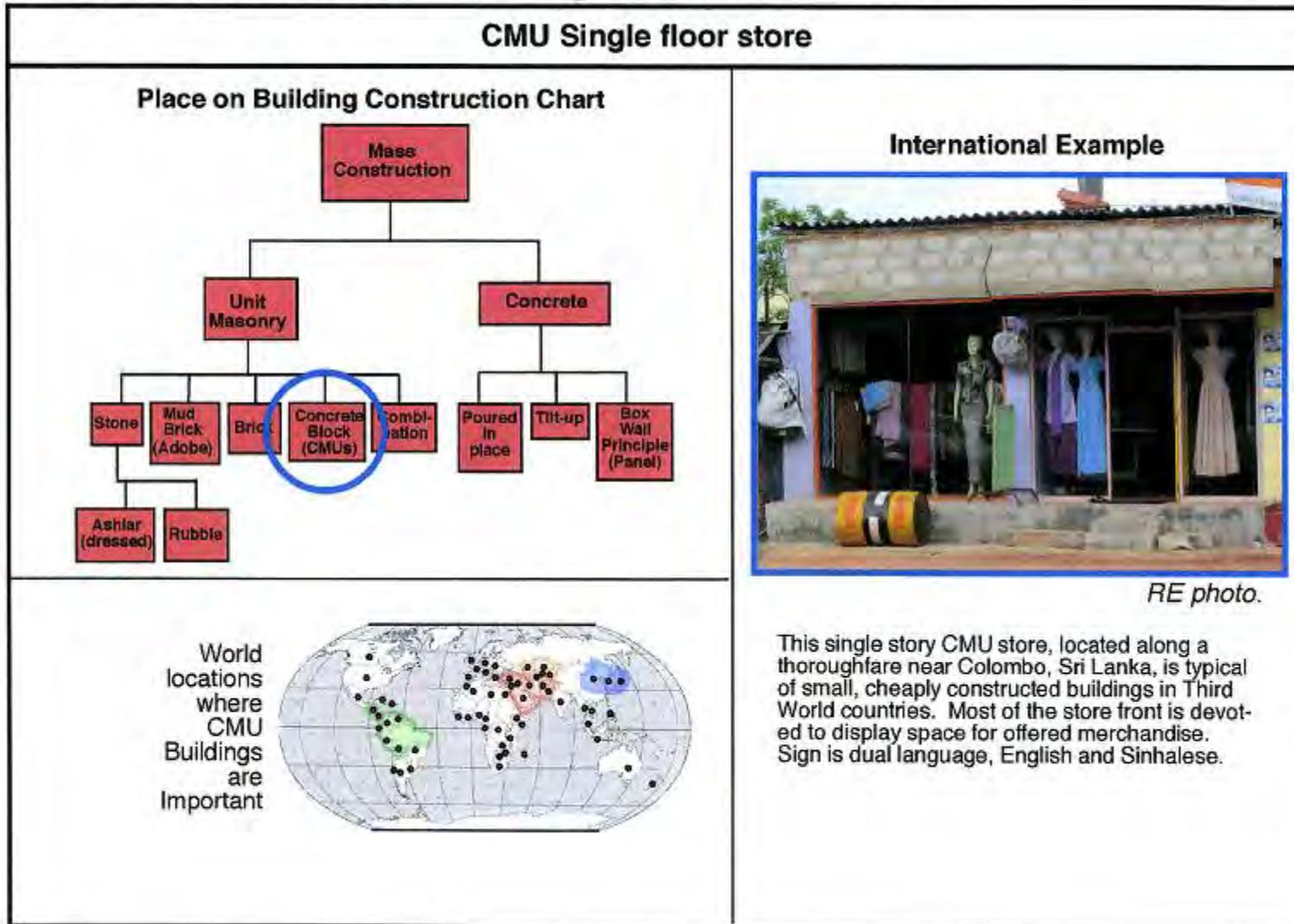


Figure 103. Mass 15-1 place on building construction chart.

Mass 15-2 Elevations

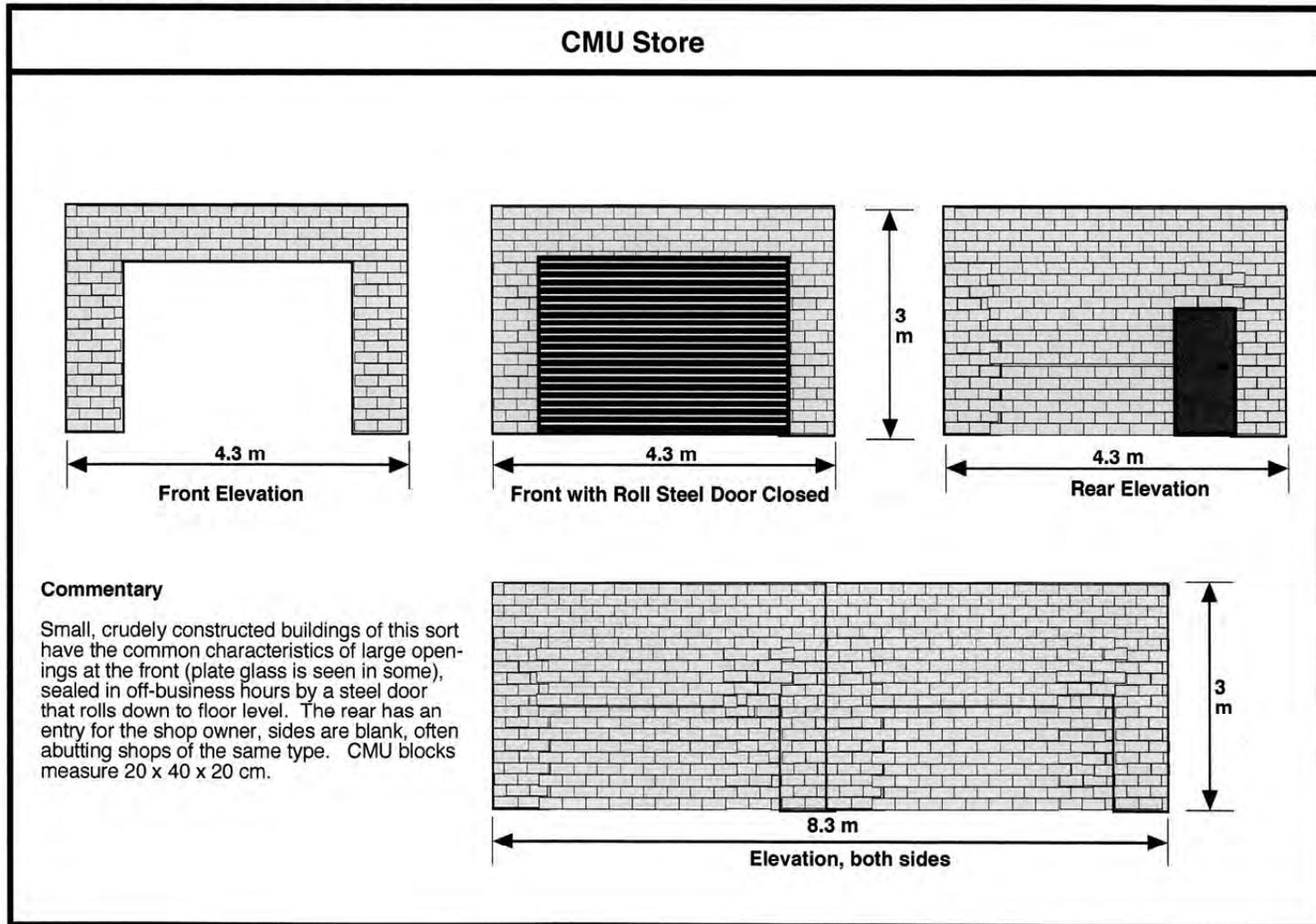


Figure 104. Mass 15-2 elevations.

Mass 15-3-a Floor Plan

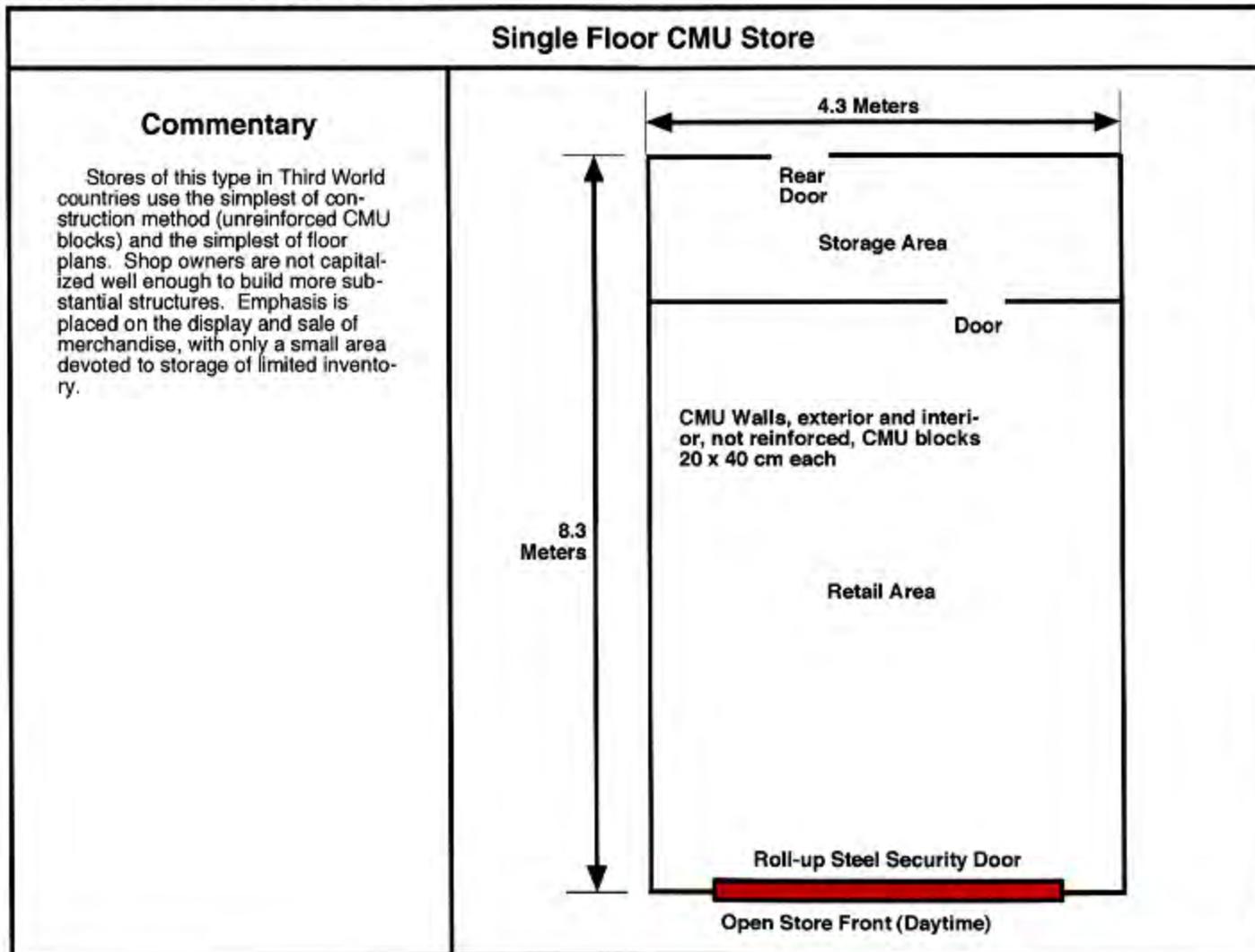


Figure 105. Mass 15-3-a floor plan.

Mass 15-4 Construction

CMU Single floor Store



Top row CMUs being laid in construction of a single story building. No rebar has been used in its construction. This form of construction is common for single story structures in Third World countries.



CMU blocks in Tel Aviv, Israel. Two styles of cavities are seen. Blocks measure 40 x 20 x 20 cm.

Mass 16-1 Place on Building Construction Chart

CMU Industrial/Storage Building

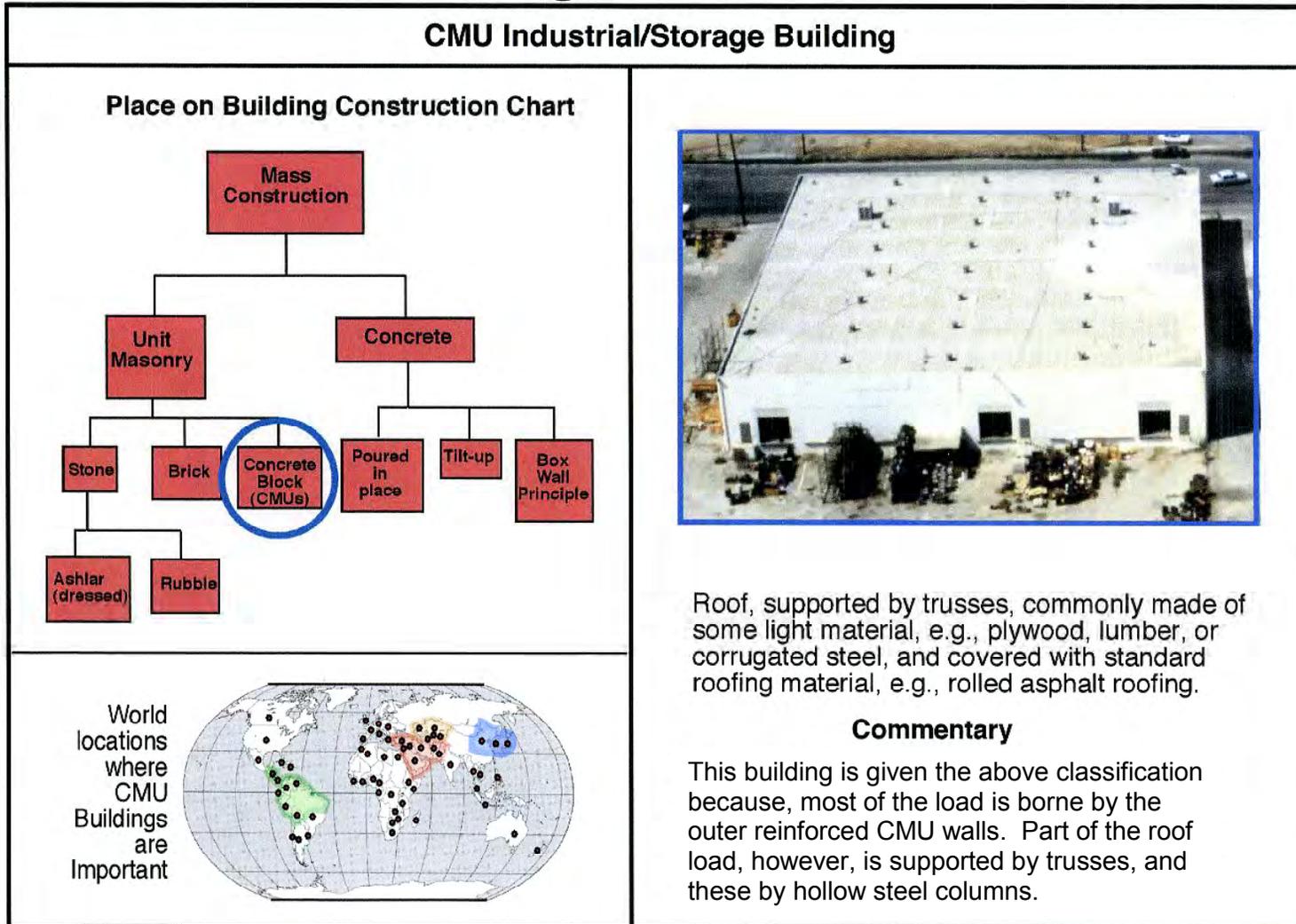


Figure 107. Mass 16-1 place on building construction chart.

Mass 16-2 Elevation

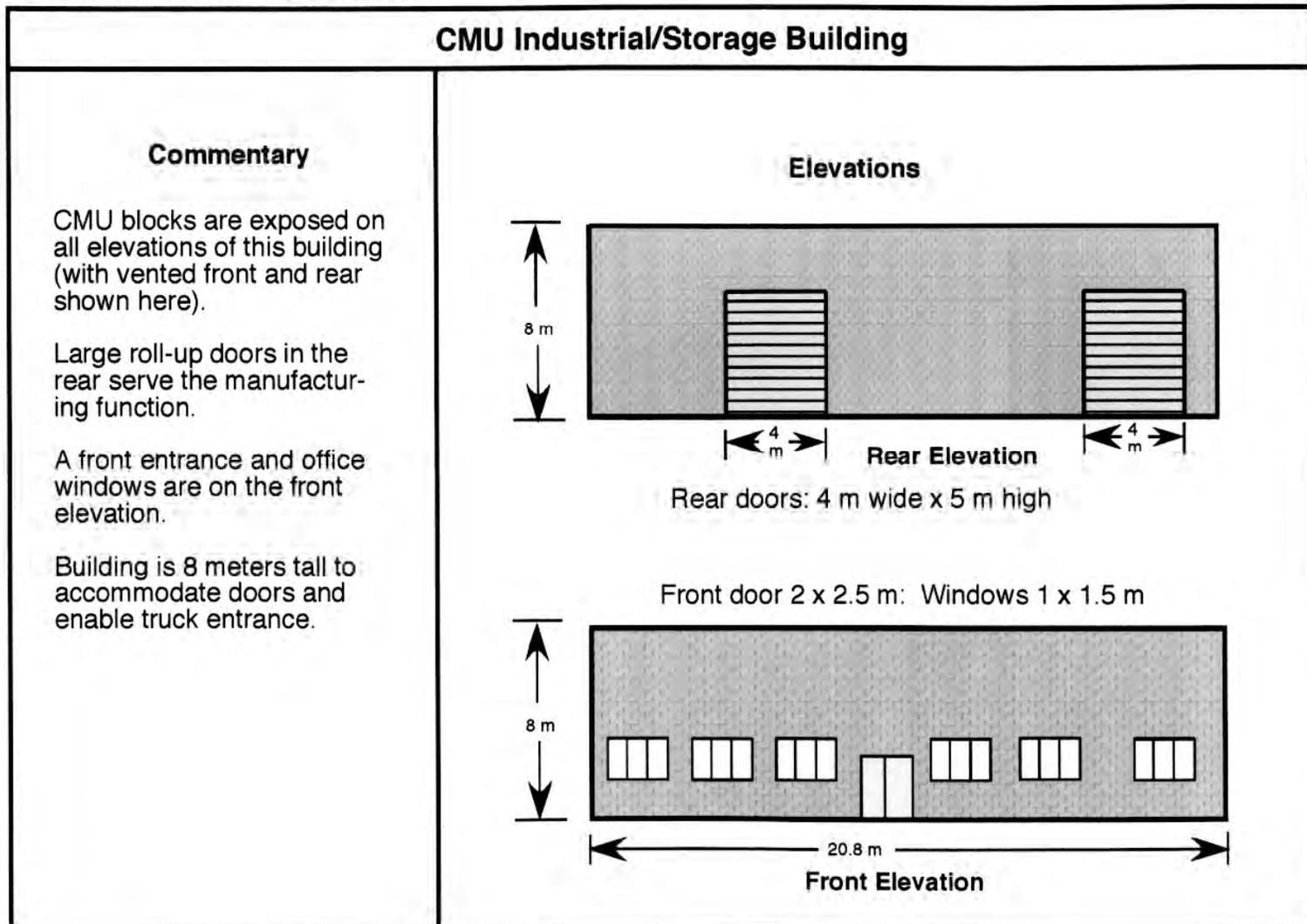


Figure 108. Mass 16-2 elevation.

Mass 16-3-a Floor Plans

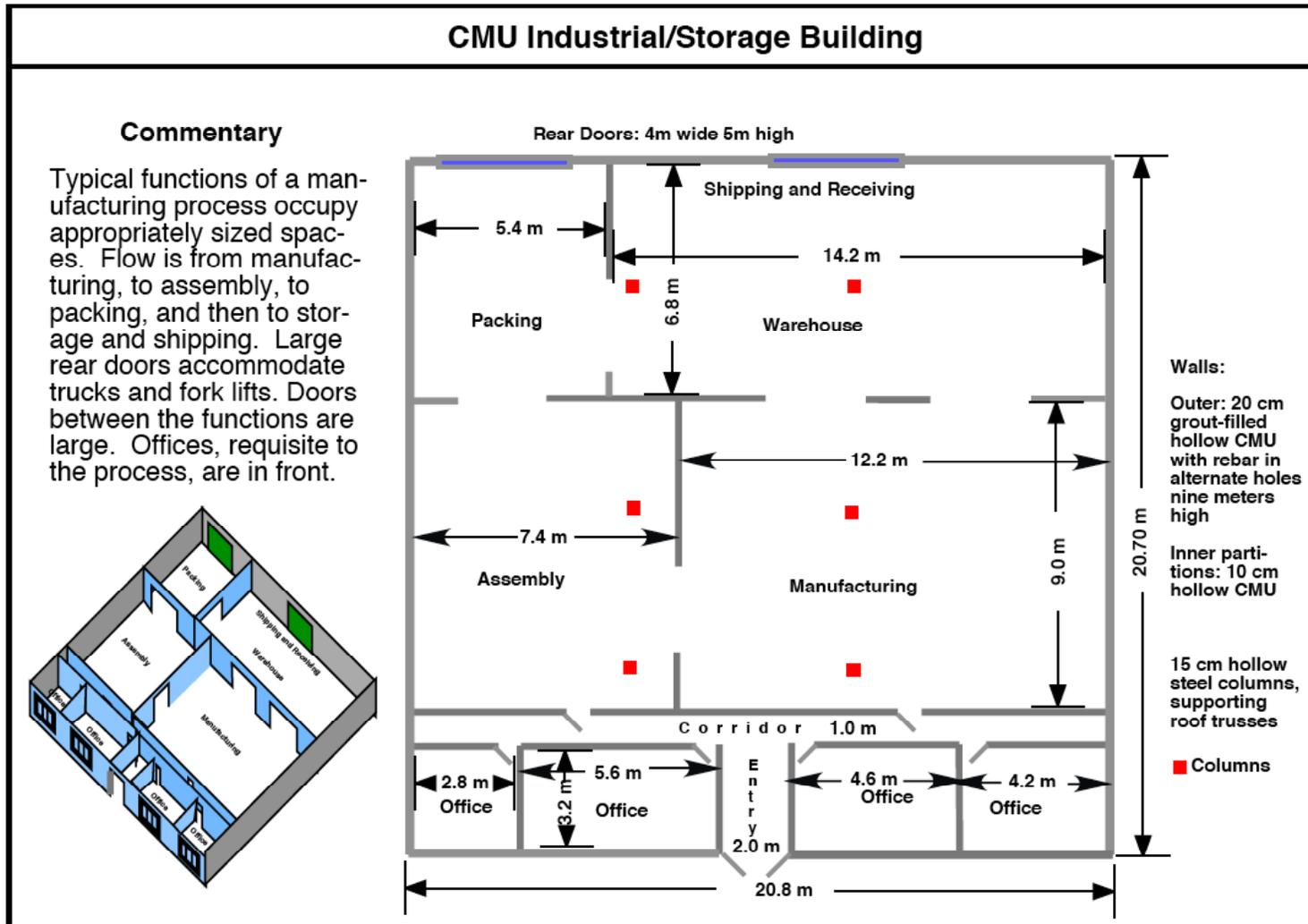


Figure 109. Mass 16-3-a floor plans.

Mass 16-3-b Isometric Floor Plan

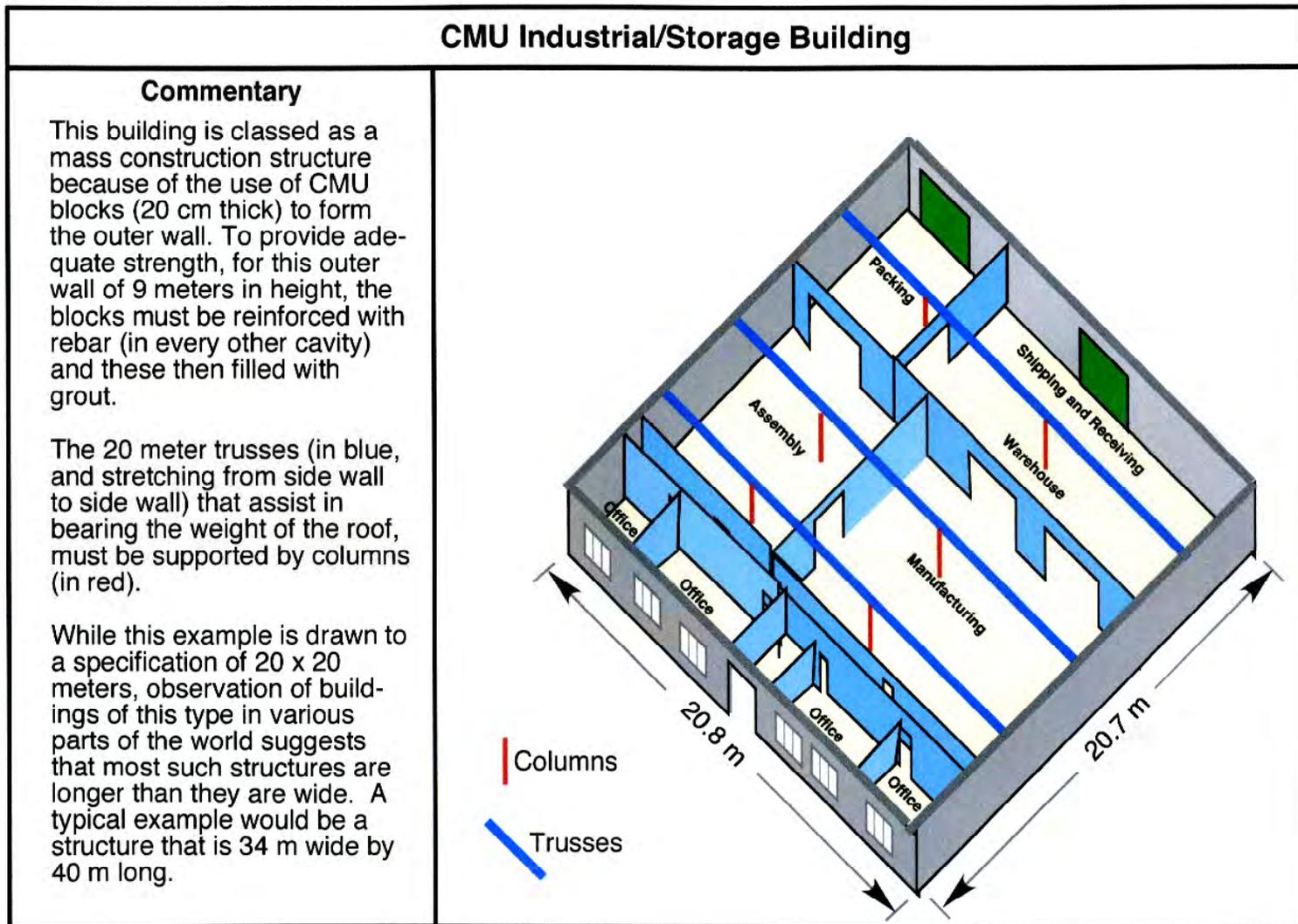


Figure 110. Mass 16-3-b isometric floor plan.

Mass 16-4 Construction

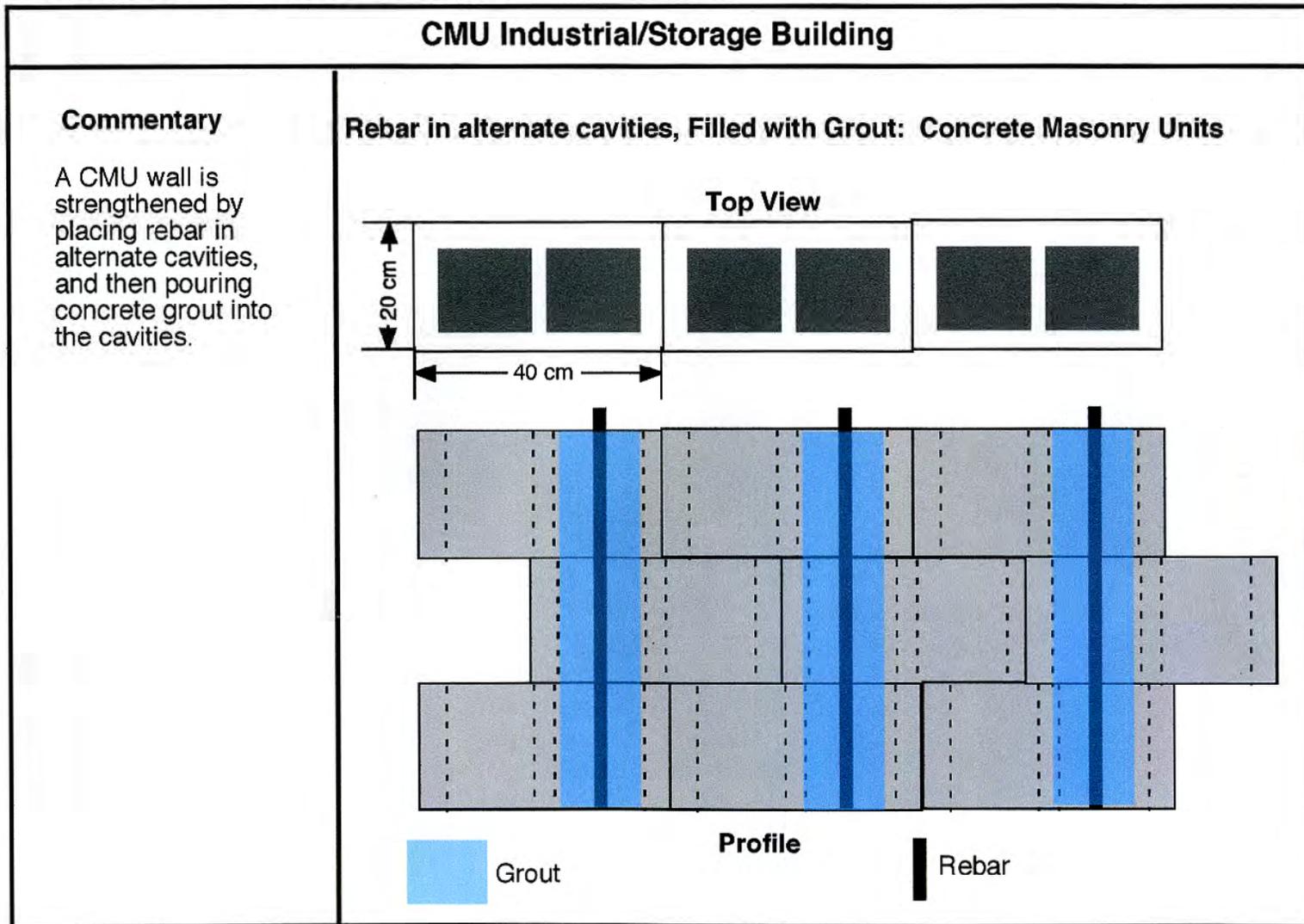
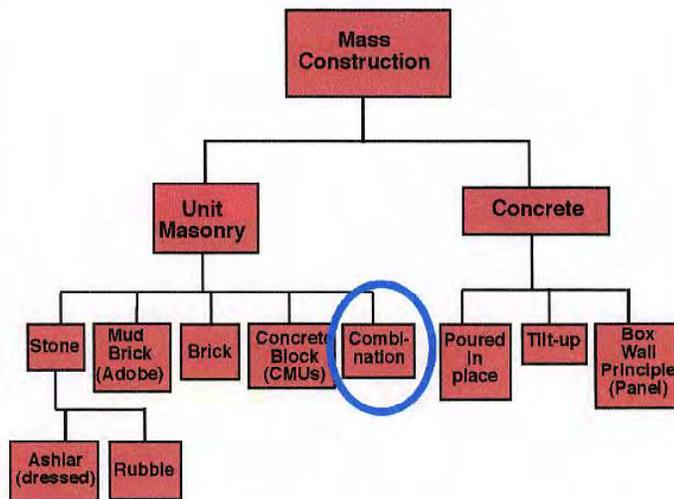


Figure 111. Mass 16-4 construction.

Mass 17-1 Place on Building Construction Chart

Brick over Block House

Place on Building Construction Chart



International Example



RE photo.

Brick over block is used in Australia for house construction, as seen in this example. Close look at the brick reveals it to have a facing pattern (only stretchers) indicating it is only one wythe thick.

World locations where brick over block is important

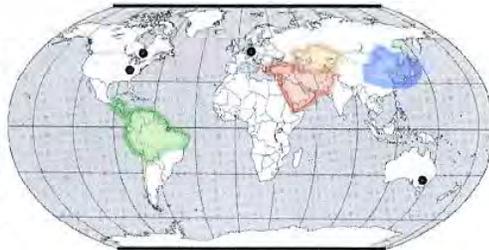


Figure 112. Mass 17-1 place on building construction chart.

Mass 17-2 Elevation and Construction

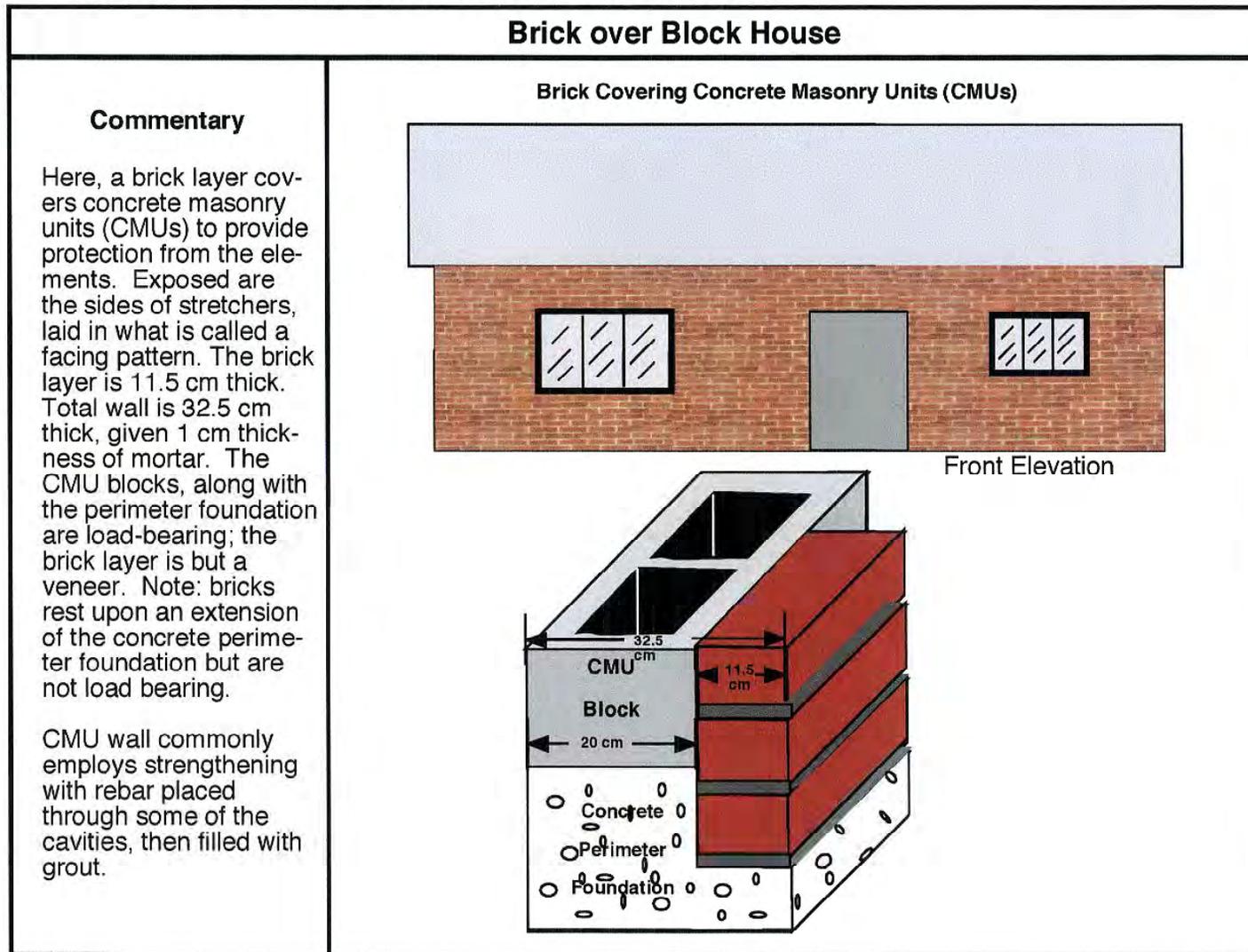


Figure 113. Mass 17-2 elevation and construction.

Mass 17-3-a Floor Plan and Construction

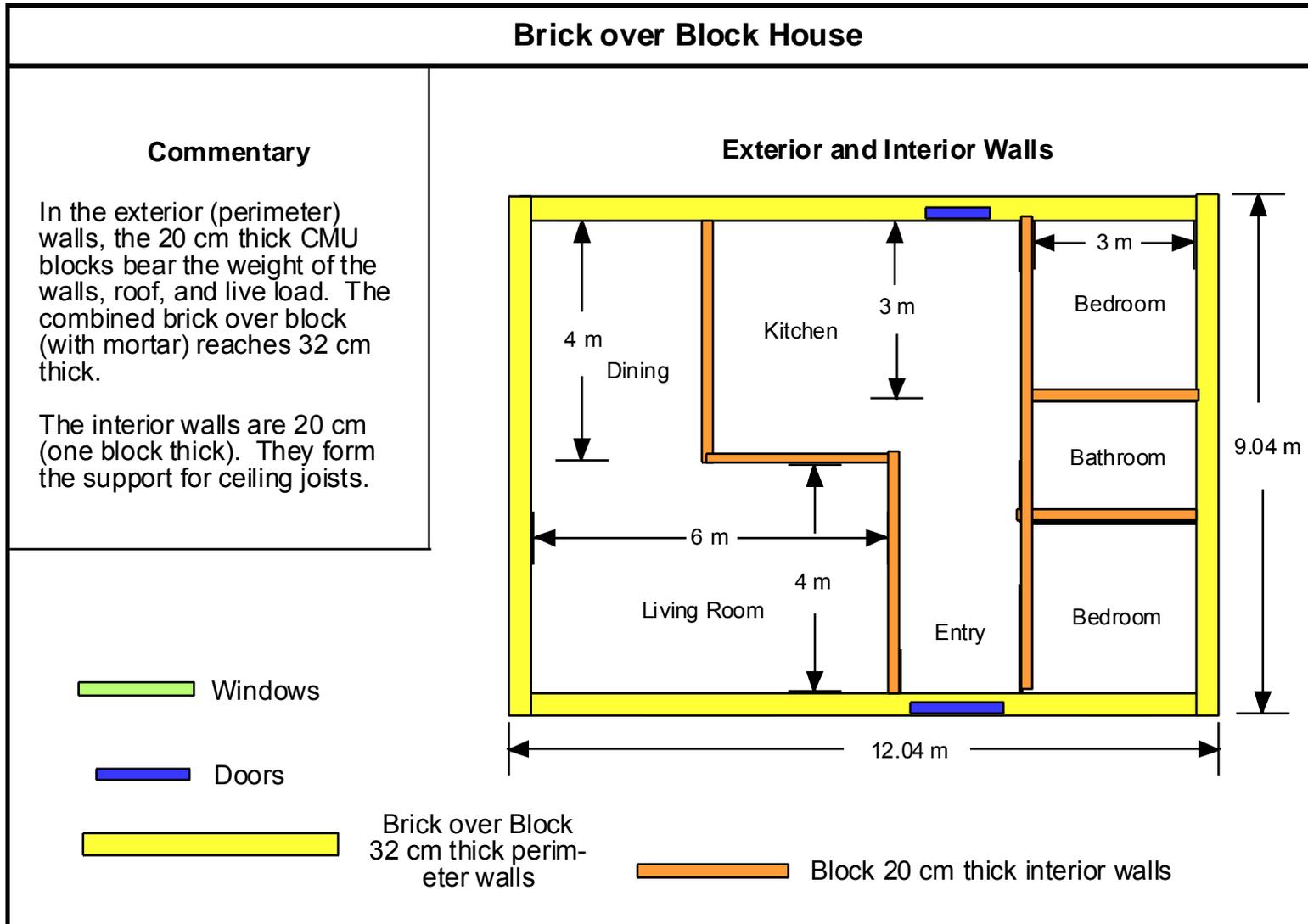


Figure 114. Mass 17-3-a floor plan and construction.

Mass 17-4 Construction

Brick over Block House

Load bearing walls

Commentary

In this full two story example, in Costa Rica, a concrete beam has been placed at the top of the row of CMUs of the ground floor as a place to connect a concrete slab floor/ceiling. The same sort of column has been built on the top of the second floor (note the forms have not been removed on the left side). A truss supported roof is in the process of construction. As can be seen in the photo, only the CMUs are an integral part of the structure. The brick facing is applied as a decorative and weather resistant cover.

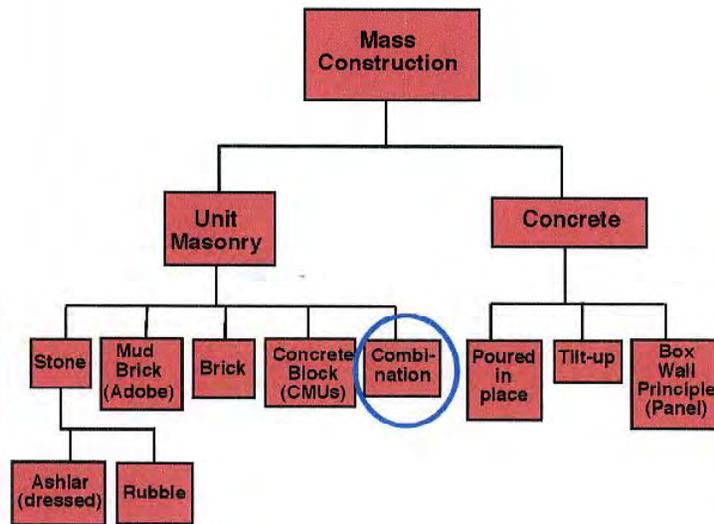


Two story CMU house under construction in Costa Rica. *RE photo.*

Mass 18-1 Place on Building Construction Chart

Mass Construction (Brick over German Building Block) 1 1/2 Story House

Place on Building Construction Chart



International Example



RE photo.

This house, in Germany, is being constructed of light building block (*lichtbaustein*) for the load-bearing exterior walls, and the load-bearing interior walls; brick will be applied as a weather sealant. Note: lintels above windows; 45 ° roof; rafter spacing; and r/c perimeter foundation.

World locations where brick over block is important

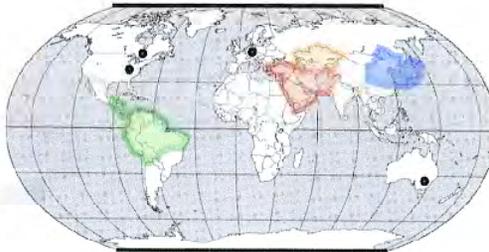
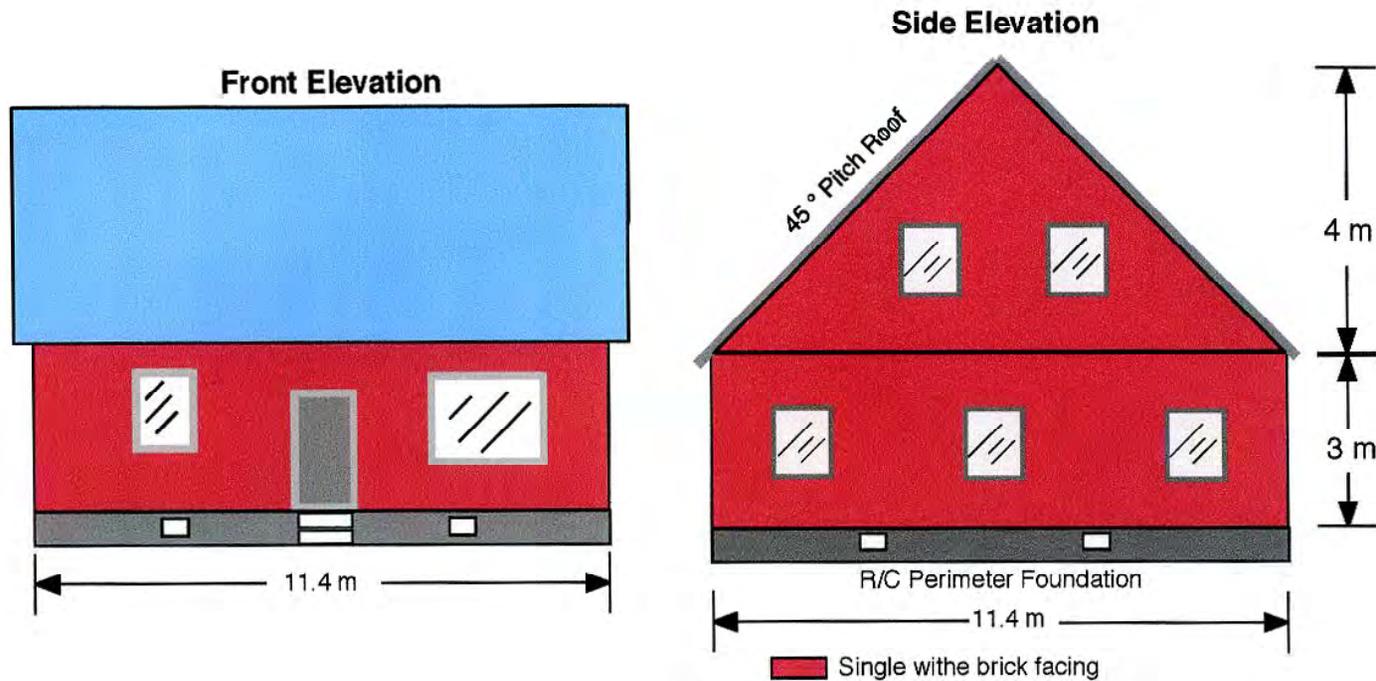


Figure 116. Mass 18-1 place on building construction chart.

Mass 18-2 Elevation

Mass Construction (Brick over German Building Block) 1 1/2 Story House



Commentary

Simple but utilitarian architectural style is employed in the design of this house. Ground floor space is 100 square meters; the attic has another 50 square meters, and the basement has another 100 square meters, and is used for storage, laundry, and utilities. The living area (ground floor and attic) thus have about 1500 square feet, with the basement space a bonus. Space is adequate for a family of four. The upper floor and the basement also make maximal use of house heating, an item of key concern in European winters.

Figure 117. Mass 18-2 elevation.

Mass 18-3-a Floor Plan

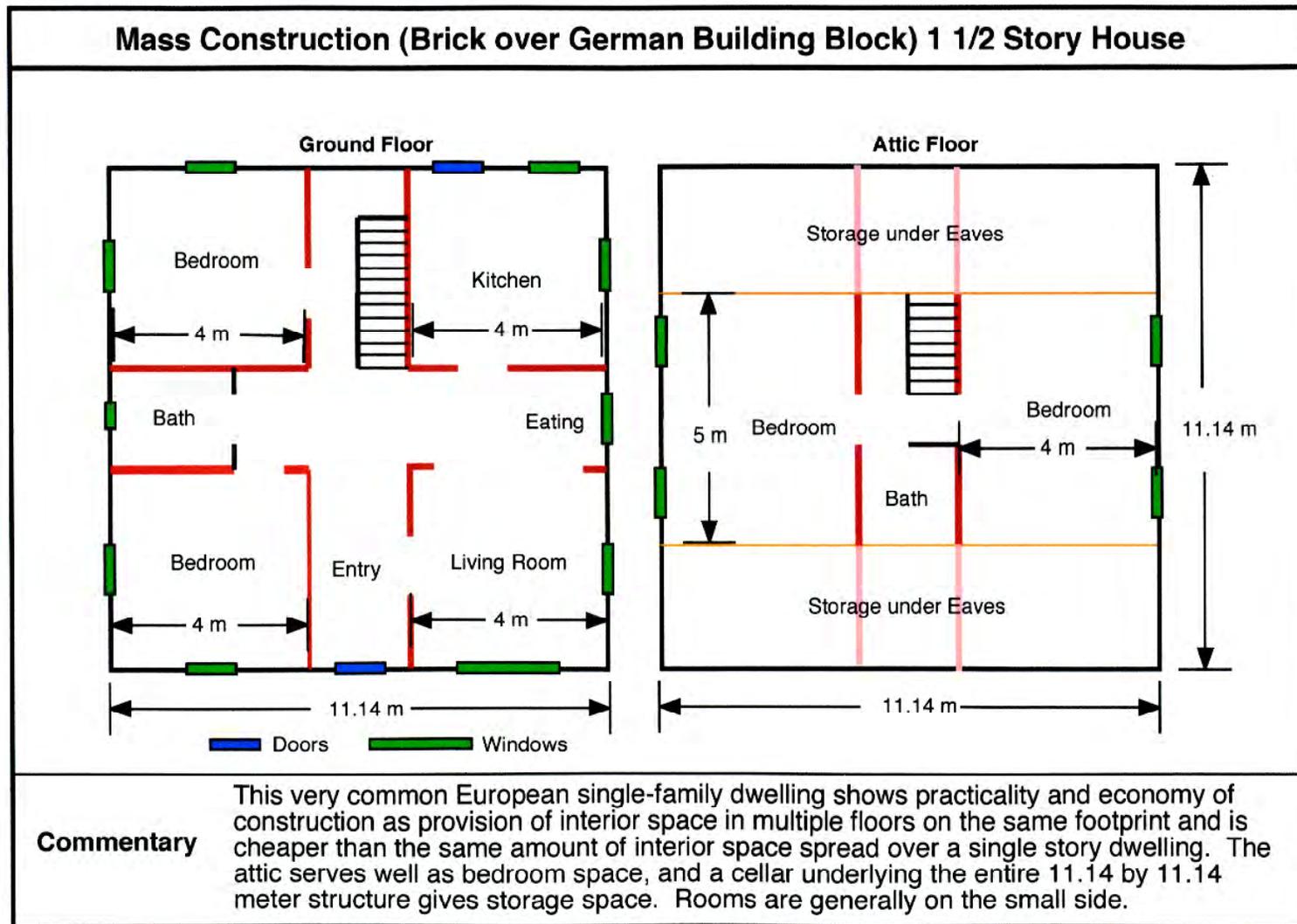


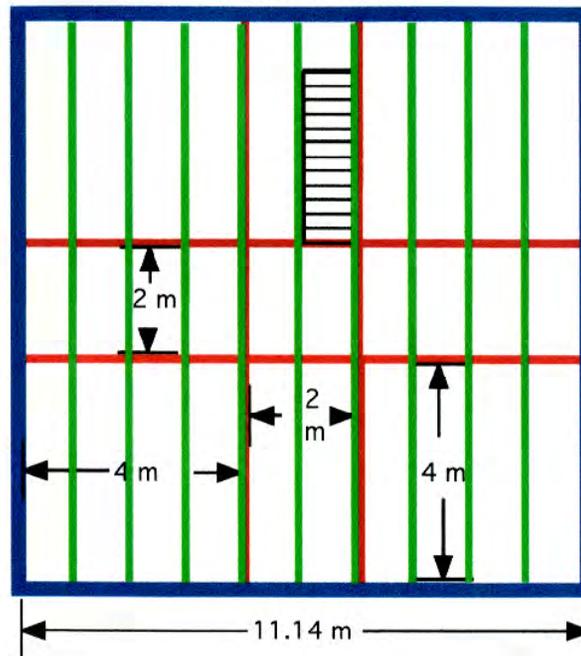
Figure 118. Mass 18-3-a floor plan.

Mass 18-4-a Construction

Mass Construction (Brick over German Building Block) 1 1/2 Story House

Construction Basics: Floor-Ceiling Joists

Ground Floor



Commentary

This mass construction building uses light building block 23 cm thick, faced with brick for sealant against the elements. Interior walls (23 cm thick for the ground floor) are made with light building block, and 11.5 cm bricks are used for the interior walls in the attic floor.

floor/ceiling joists

Exterior load-bearing wall "light building block" is 23 cm thick; facing brick is 11.5 cm, for a combined 35.5 cm thick

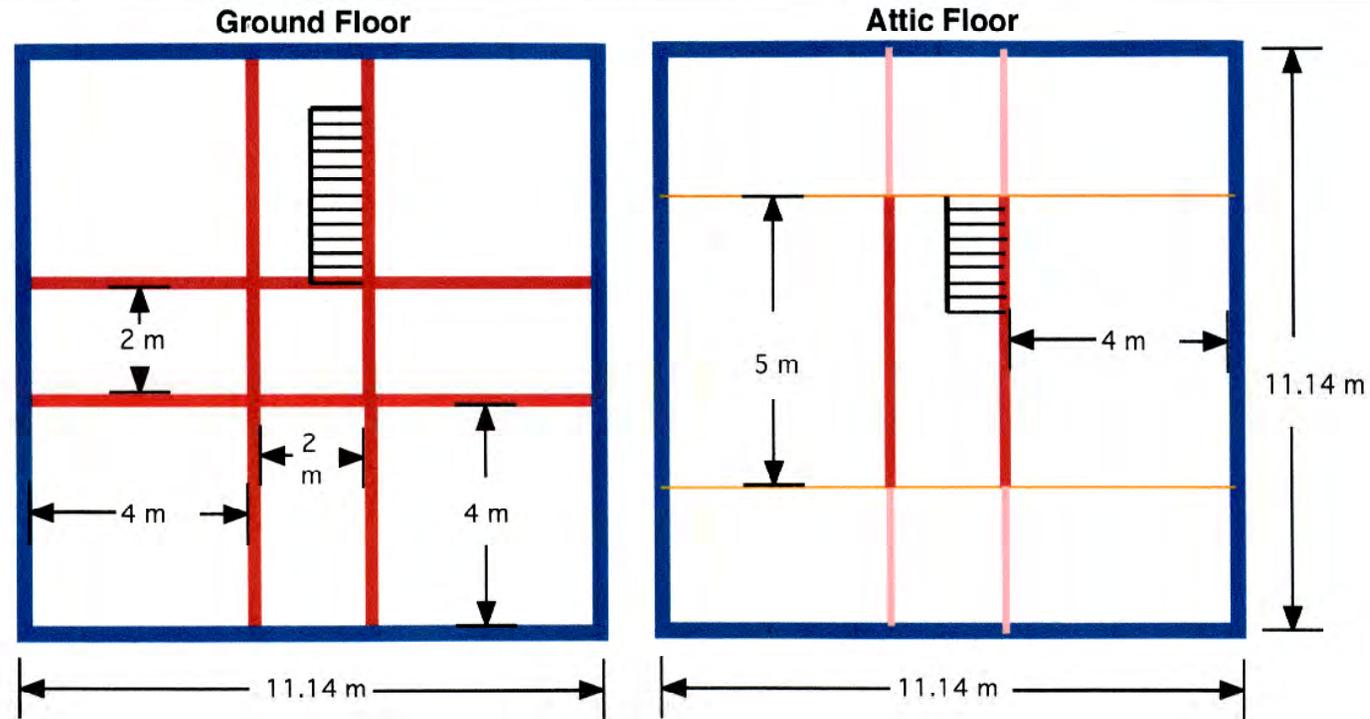
Interior load-bearing wall 23 cm ground floor, 11.5 cm attic floor

Figure 119. Mass 18-4-a construction.

Mass 18-4-b Construction

Mass Construction (Brick over German Building Block) 1 1/2 Story House

Construction Basics: Load-Bearing Walls



Commentary

This mass construction building uses light building block 23 cm thick, faced with brick for sealant against the elements. Interior walls (23 cm thick for the ground floor) are made with light building block, and 11.5 cm bricks are used for the interior walls in the attic floor.

- █ Exterior load-bearing wall
light building block is 23 cm thick; facing brick is 11.5 cm thick, for a combined 35.5 cm.
- █ Interior load-bearing wall
23 cm ground floor, 11.5 cm attic floor

Figure 120. Mass 18-4-b construction.

Mass 18-4-c Construction

Mass Construction (Brick over German Building Block) 1 1/2 Story House

Construction: Light Building Block with Brick Cover

Commentary

A form of mass construction common in Western Europe employs a large (46 x 23 x 23 cm) building block made of composition materials and light in weight. These blocks are not formed with holes for the placement of rebar; their large size alone provides the necessary strength to uphold all structural loads.

Their light material, however, requires a protective cover from the elements. Stucco is often used, and in this example, courses of brick are mortared to the building block.

This front elevation shows the windows for the living room on the left and the dining room on the right, with the front entry door in the middle.

Front Elevation

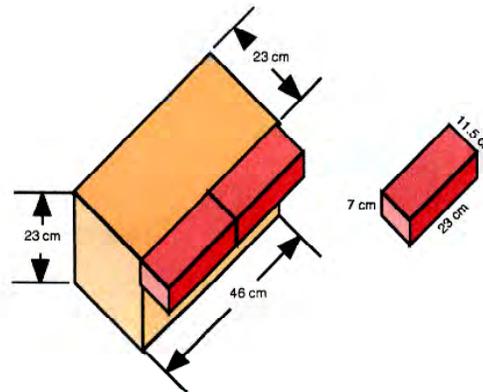
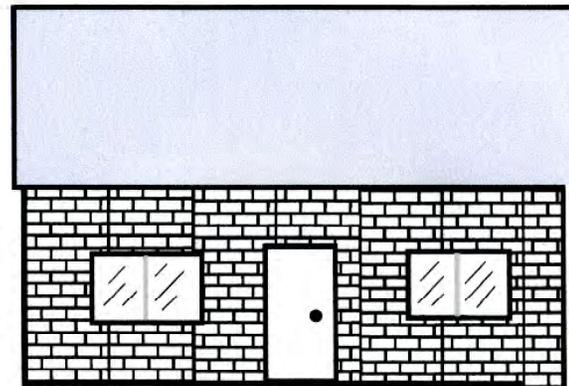


Figure 121. Mass 18-4-c construction.

Mass 19-1 Place on Building Construction Chart

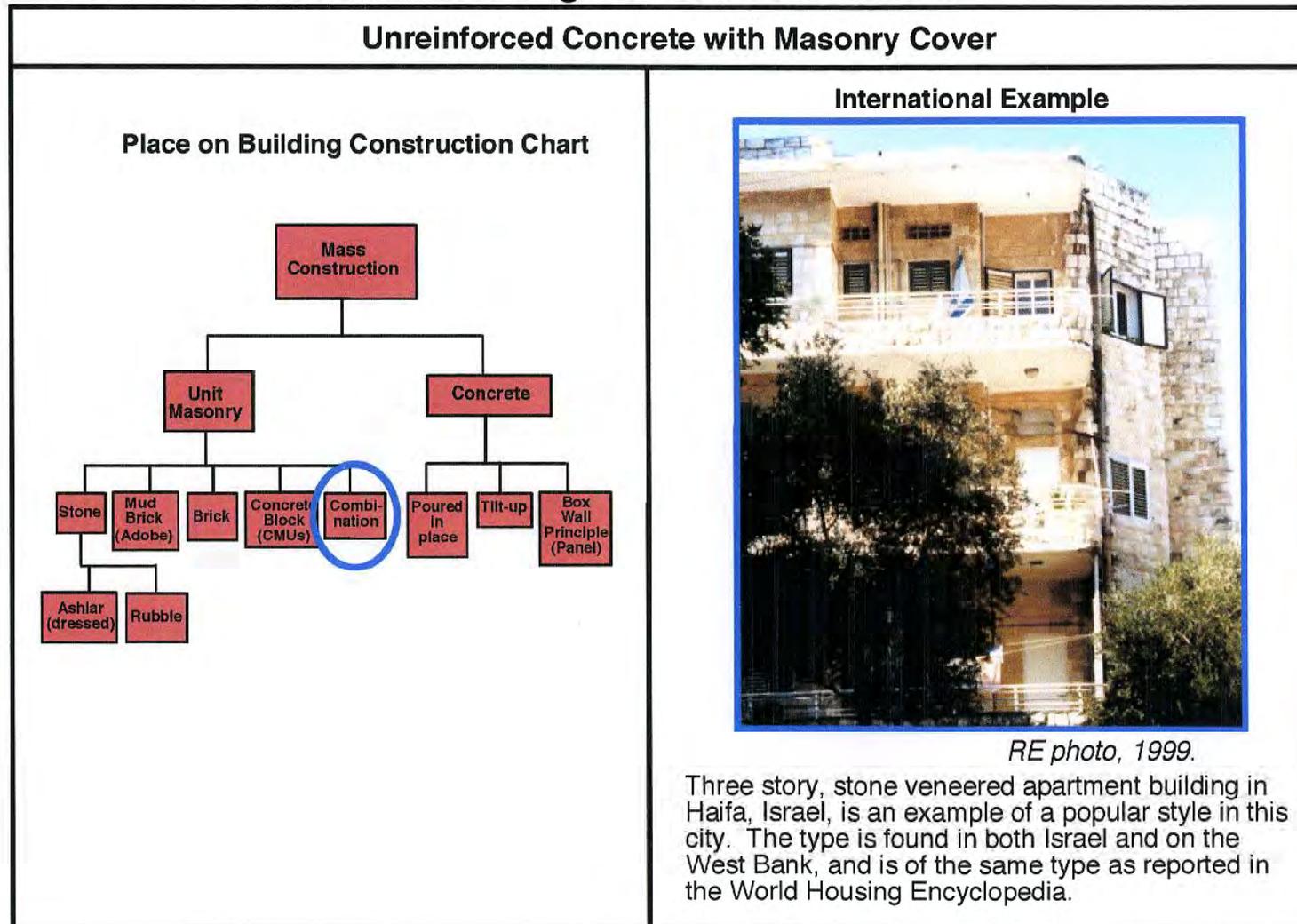


Figure 122. Mass 19-1 place on building construction chart.

Mass 19-2 Elevation

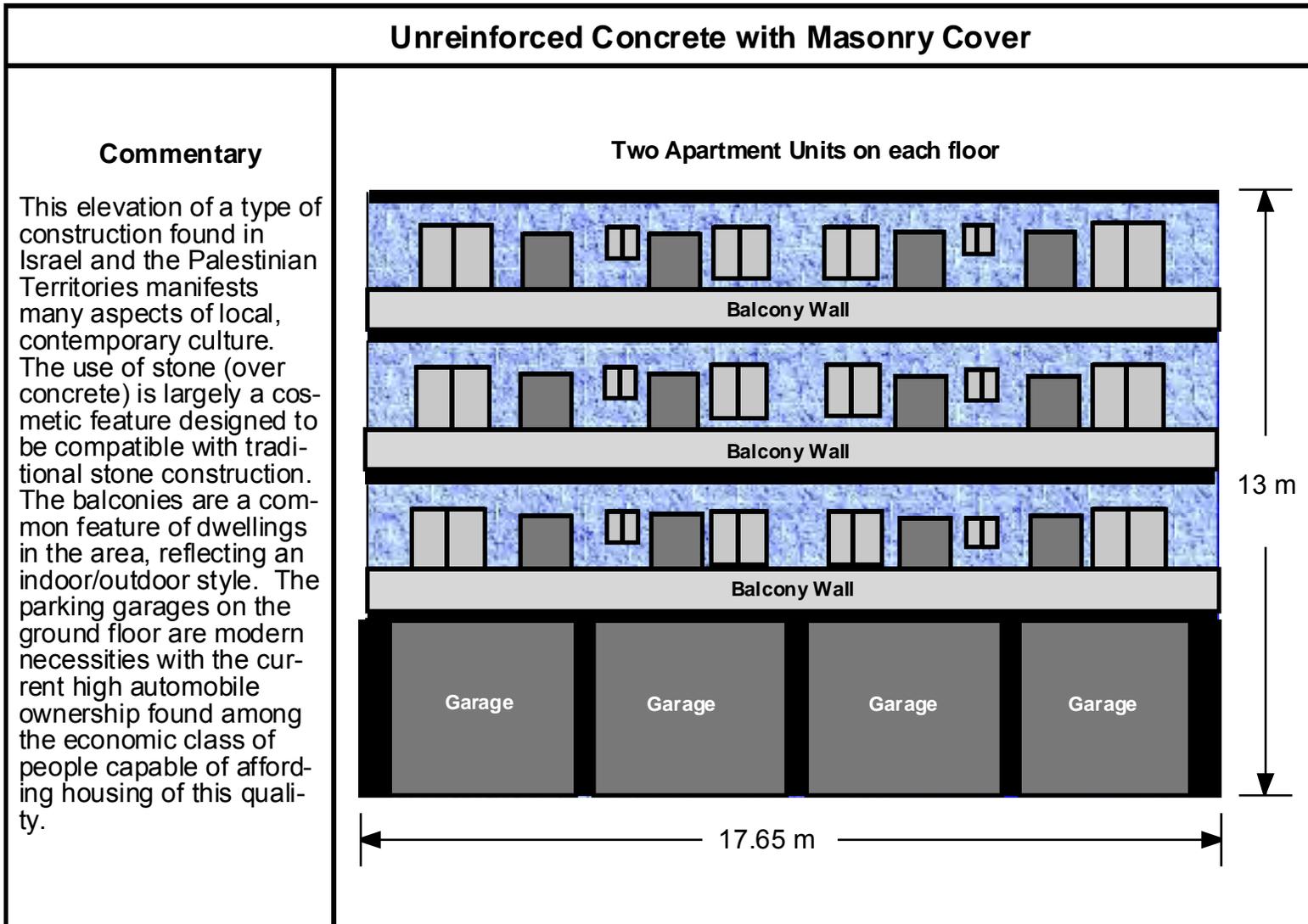


Figure 123. Mass 19-2 elevation.

Mass 19-3-b Isometric Floor Plan

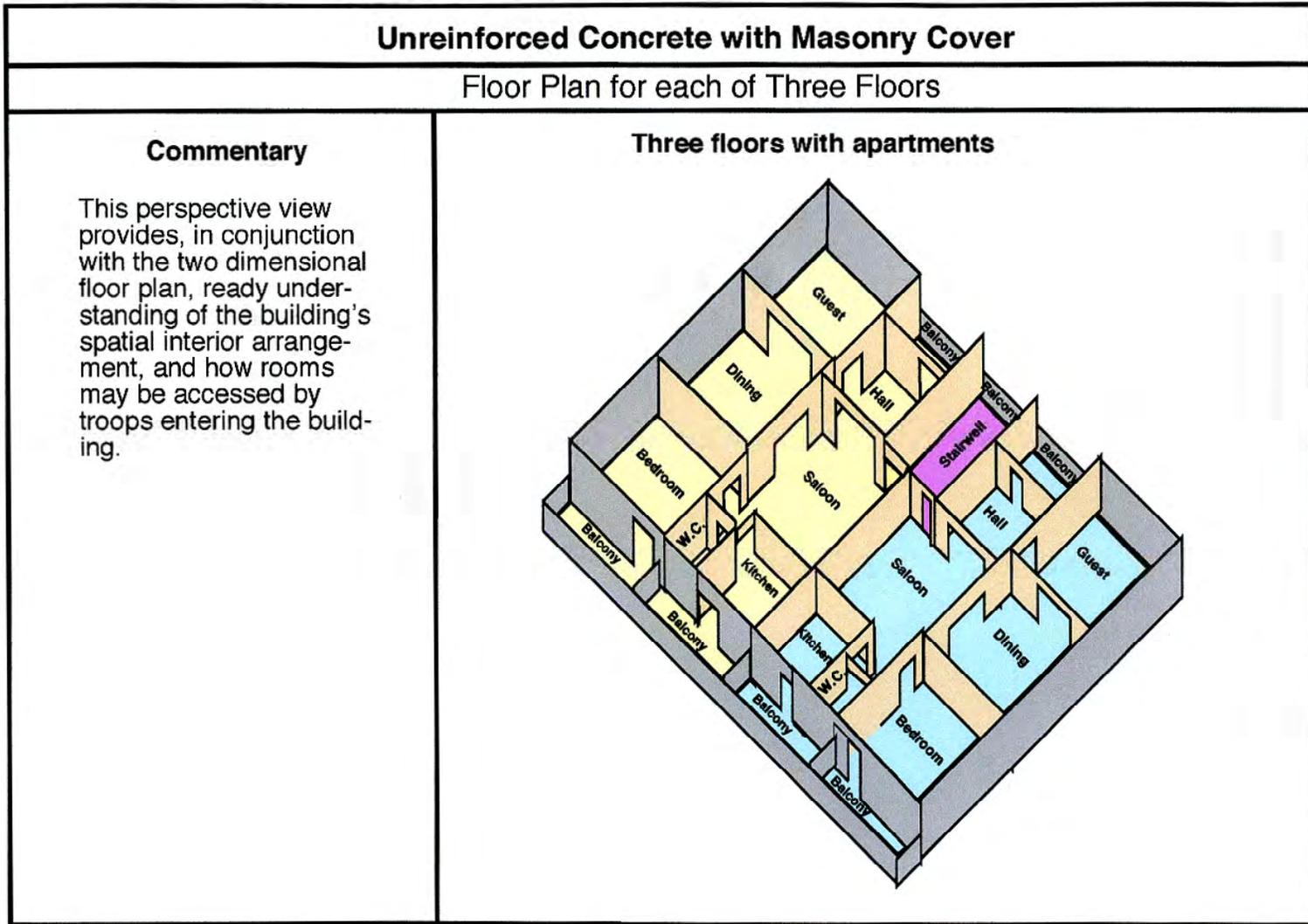


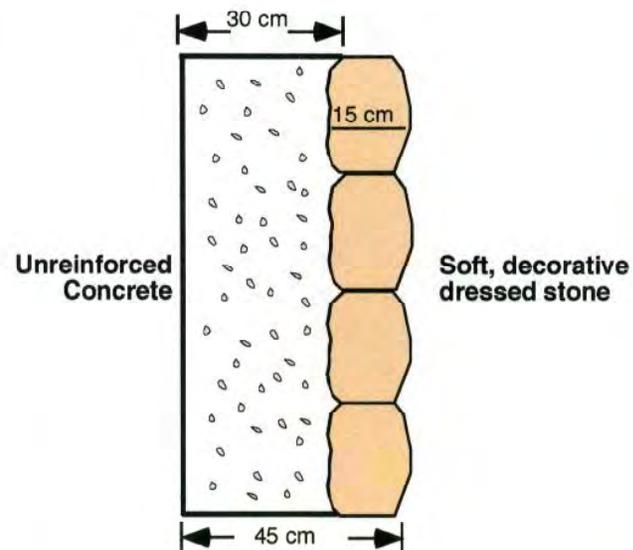
Figure 125. Mass 19-3-b isometric floor plan.

Mass 19-4 Construction Method and Dimensions

Unreinforced Concrete with Stone Cover

Example in Israel

Exterior wall cross-section



RE photo.

Commentary

Cross section of load-bearing exterior wall. Unreinforced concrete and masonry apartment building. Walls are very thick but stone is soft and concrete is not reinforced with steel.

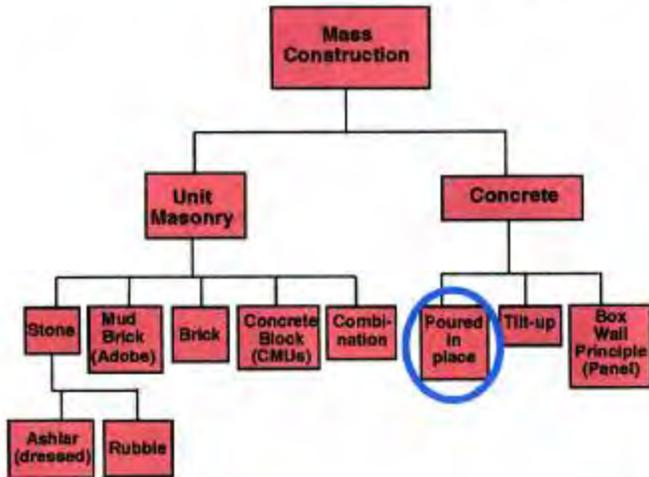
Decorative stone being applied over a concrete wall. The concrete load-bearing wall provides supporting strength, the various shaped stone forms a veneer. In Haifa, Israel.

Figure 126. Mass 19-4 construction method and dimensions.

Mass 20-1 Place on Building Construction Chart

Poured-in-Place (with Pilasters) Large, 1 Story Retail Store

Place on Building Construction Chart



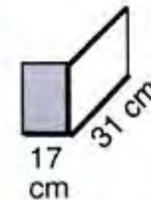
Photograph of an Example



RE photos



Store front, above, has large display windows. Concrete pilasters (at left) on side walls of this building add strength to exterior walls.



Pilaster to the left measures 17 x 31 cm. Dimensions and shape vary (from rectangular to square).

World locations where Poured-in-Place Buildings are important

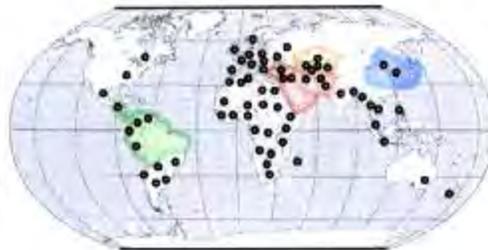


Figure 127. Mass 20-1 place on building construction chart.

Mass 20-2 Elevation

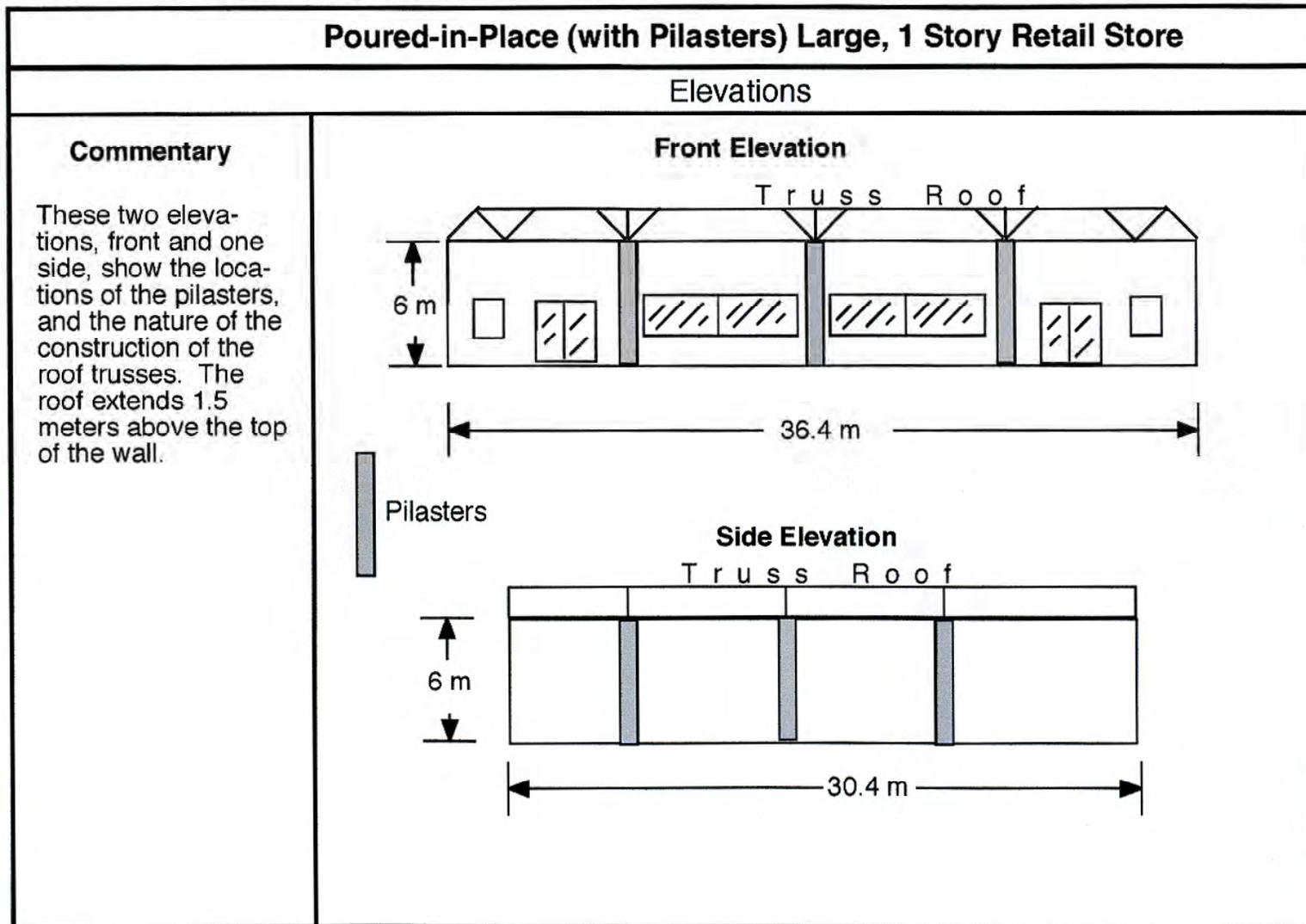


Figure 128. Mass 20-2 elevation.

Mass 20-3-a Floor Plan

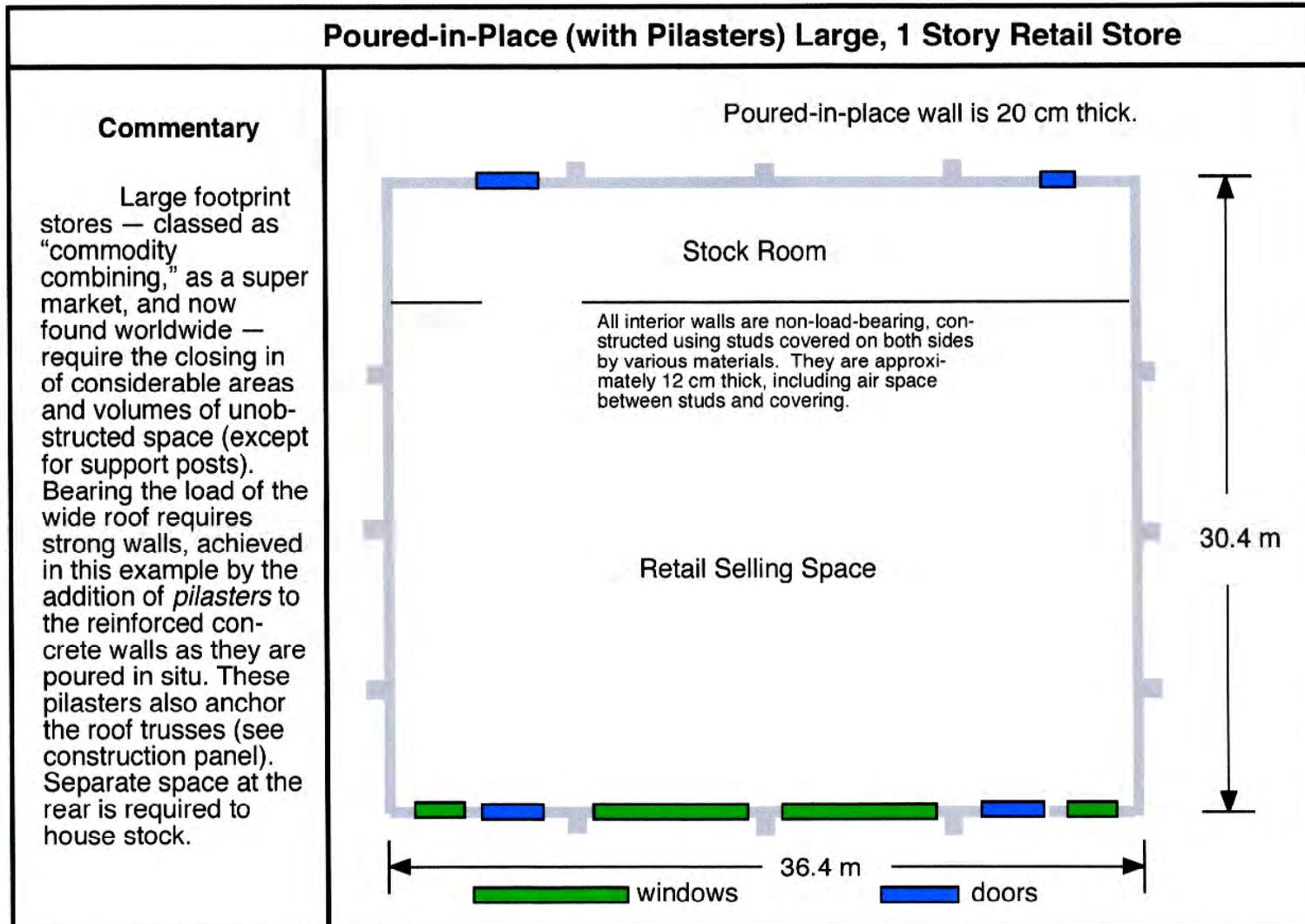
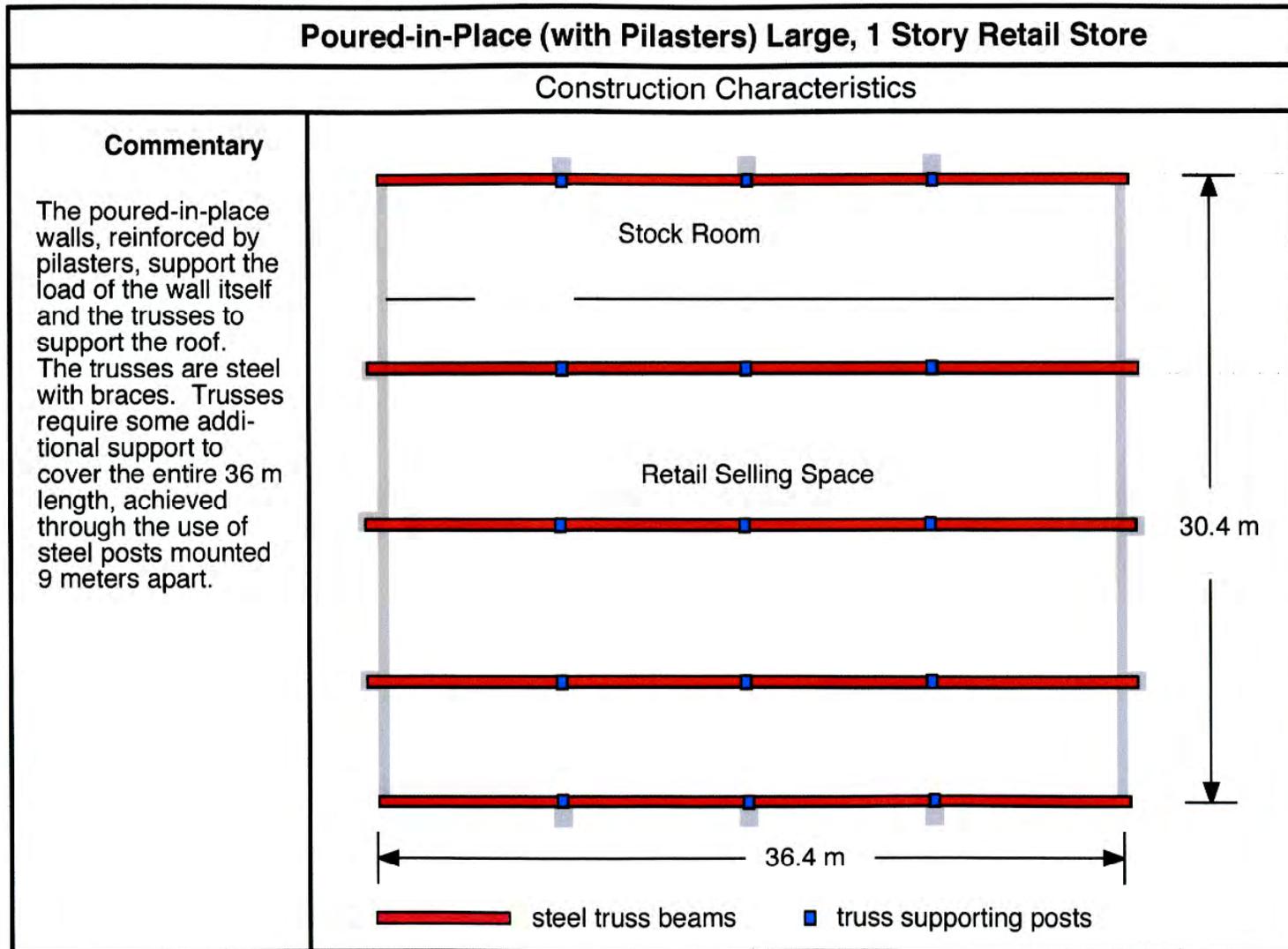


Figure 129. Mass 20-3-a floor plan.

Mass 20-4 Construction



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Figure 130. Mass 20-4 construction.

Mass 21-1 Place on Building Construction Chart

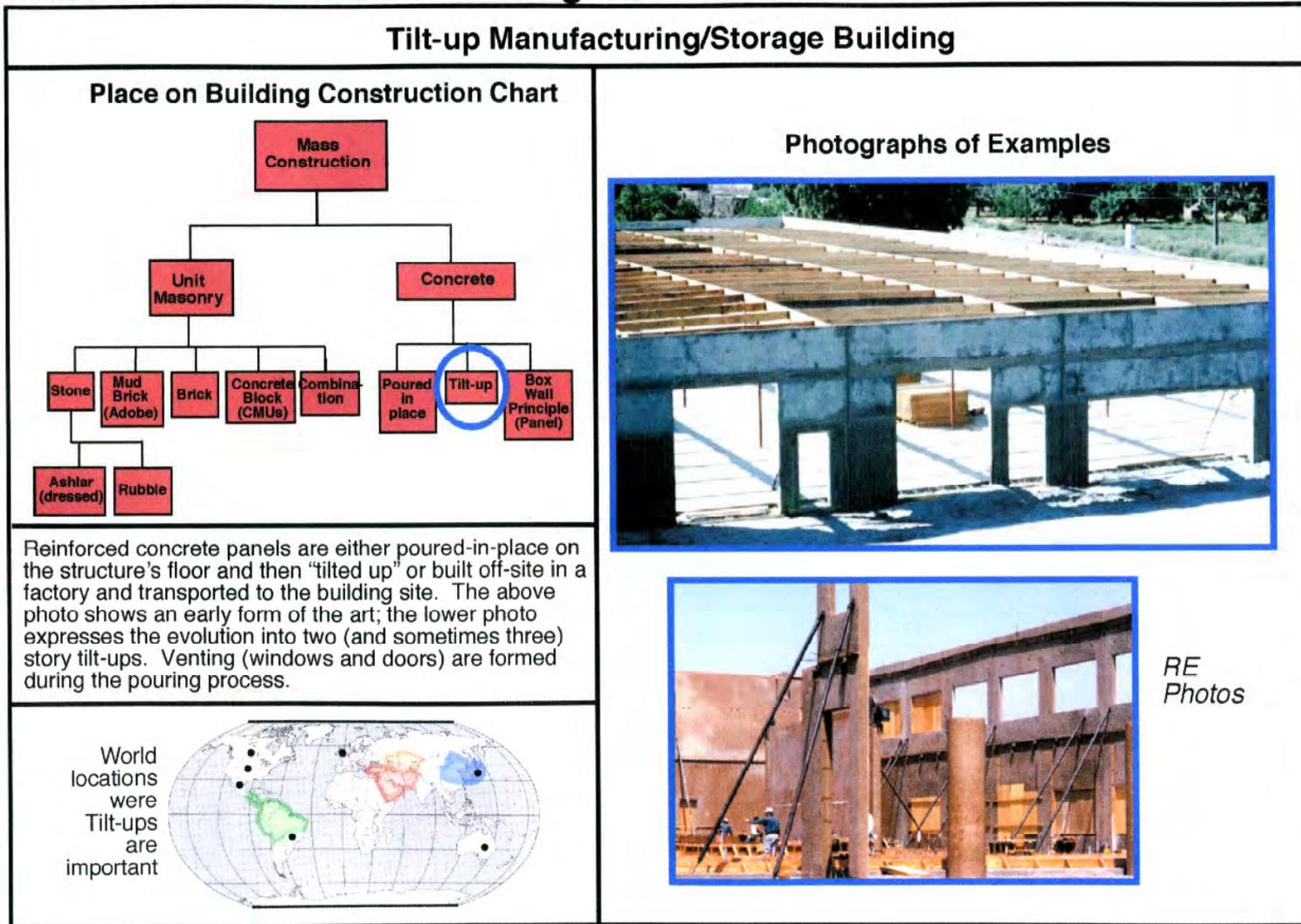


Figure 131. Mass 21-1 place on building construction chart.

Mass 21-2 Elevations

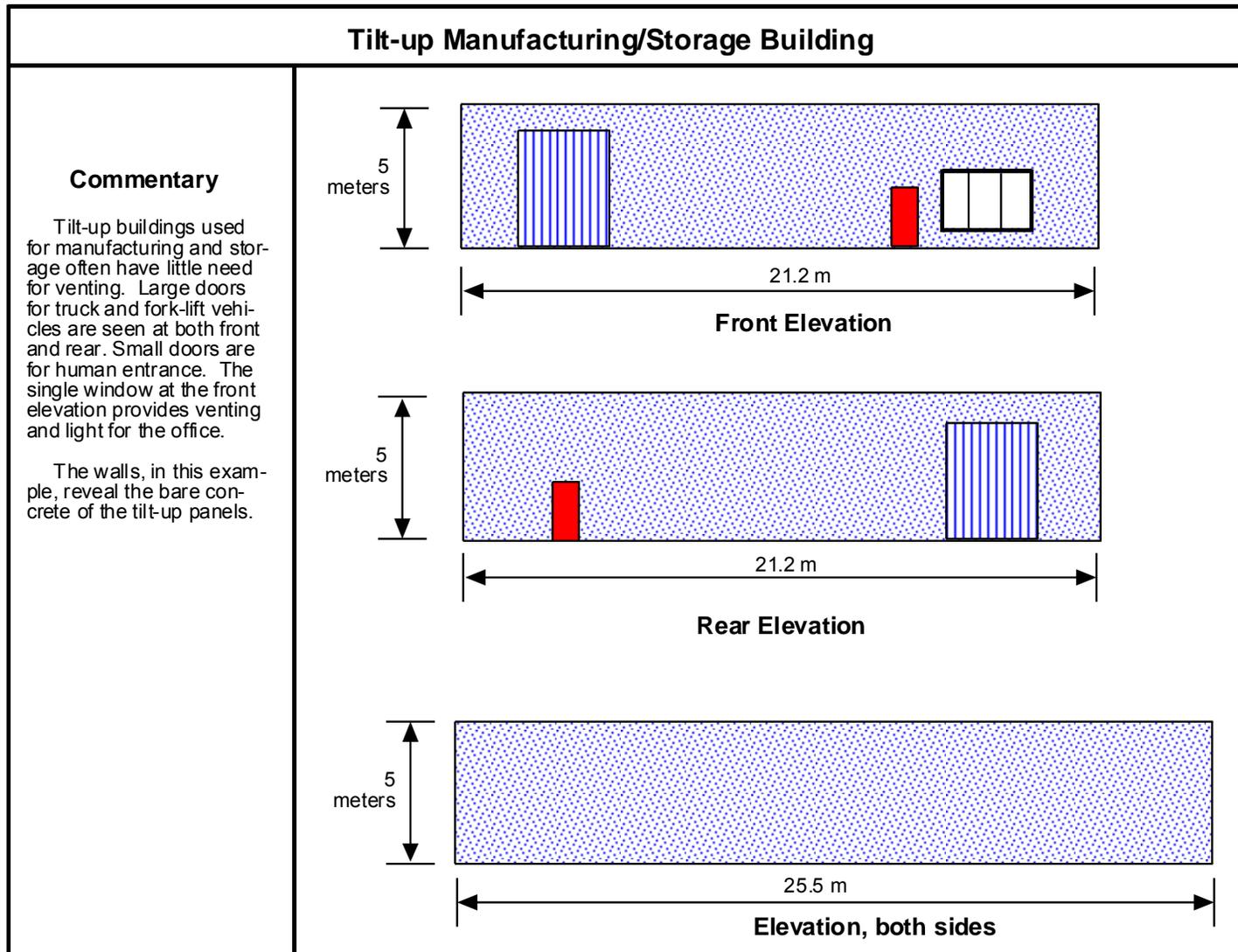


Figure 132. Mass 21-2 elevations.

Mass 21-3-a Floor Plan

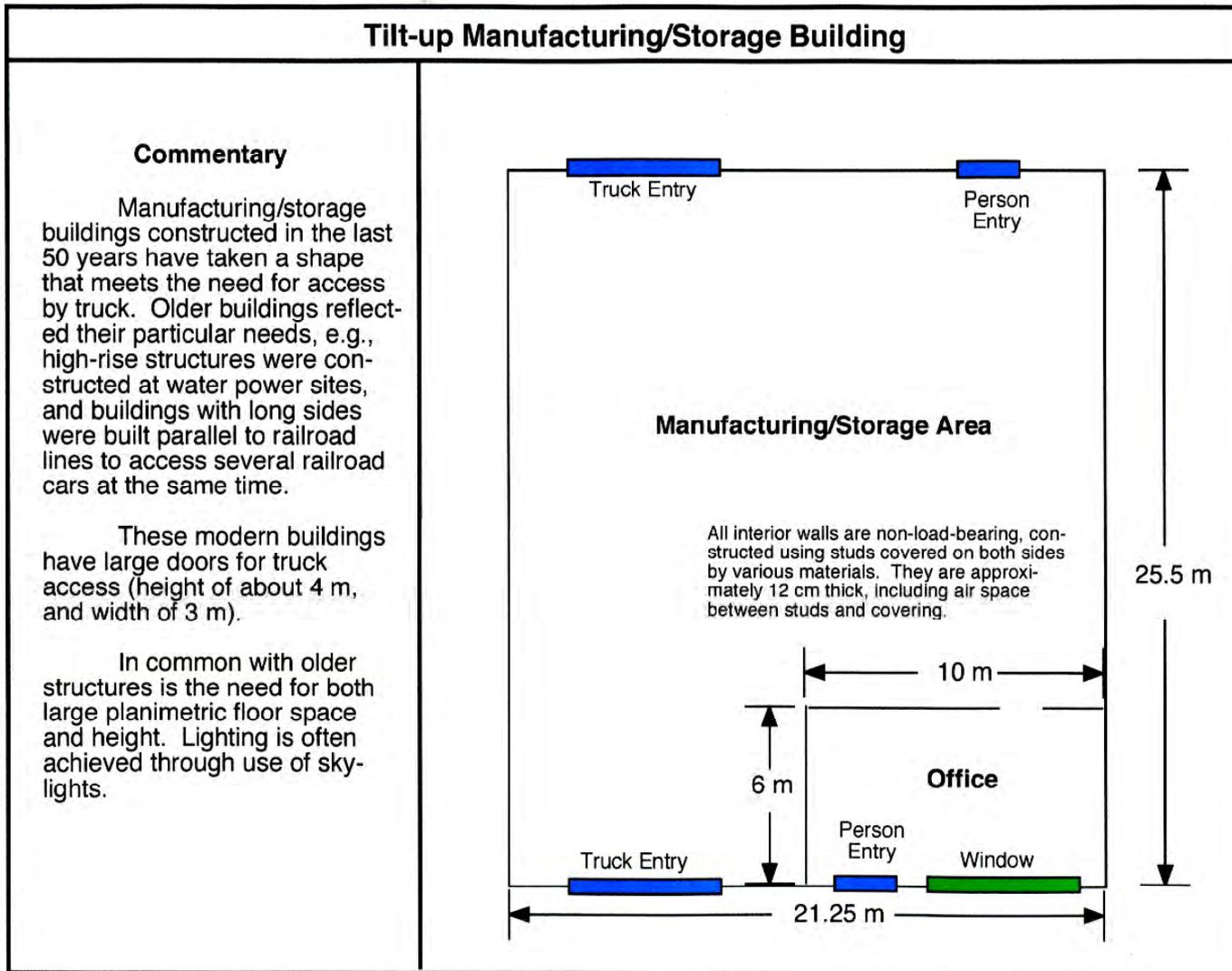


Figure 133. Mass 21-3-a floor plan.

Mass 21-4-a Construction

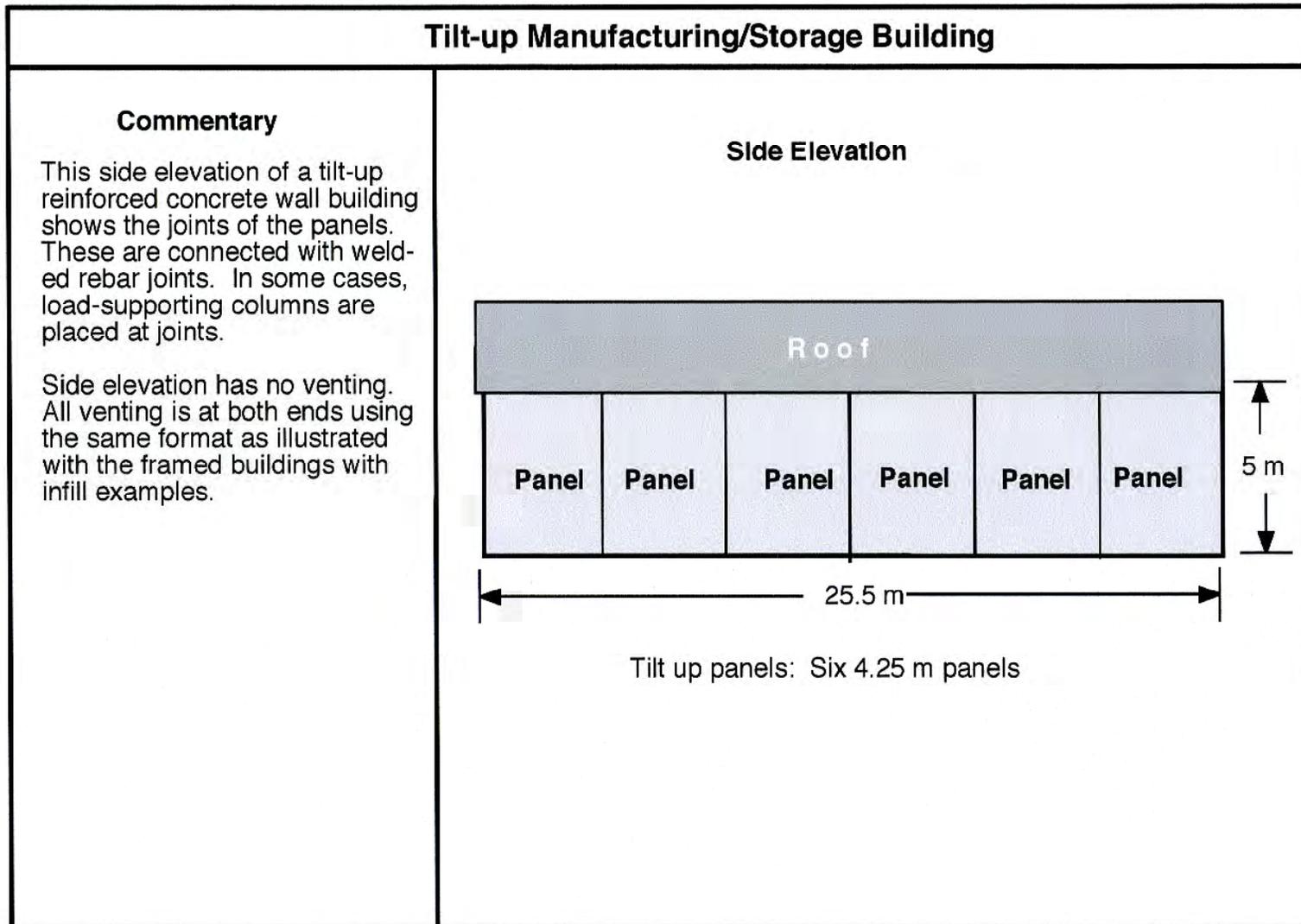


Figure 134. Mass 21-4-a construction.

Mass 21-4-b Construction

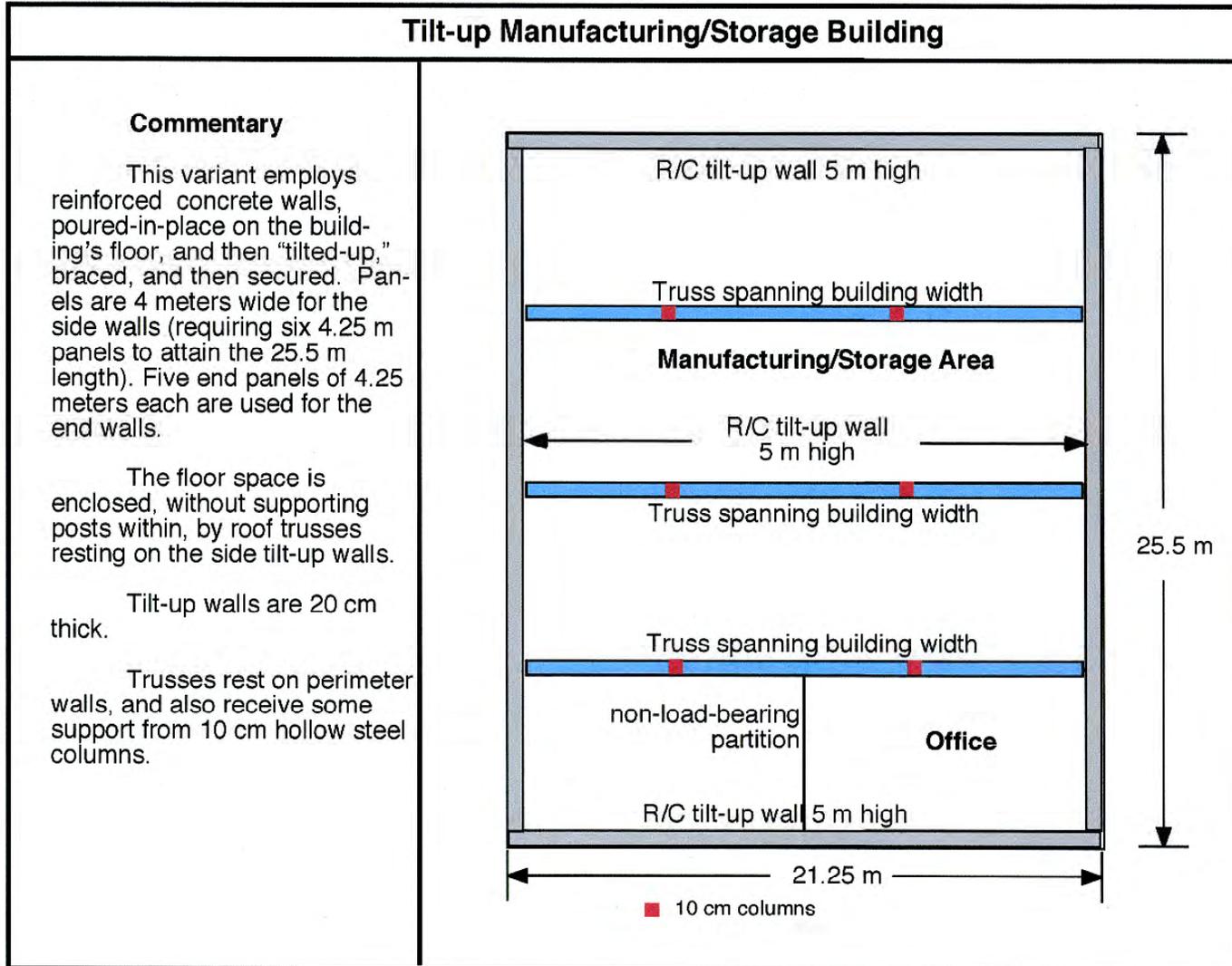
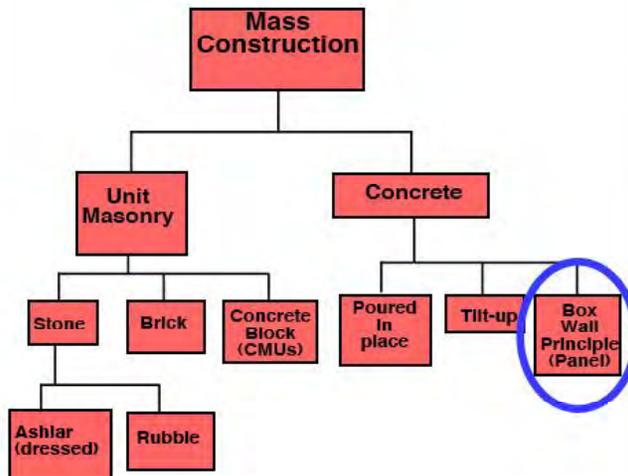


Figure 135. Mass 21-4-b construction.

Mass 22-1 Place on Building Construction Chart

Box-Wall Principle Apartment Building

Place on Building Construction Chart



International Example



RE photo 2004

This panel wall structure is part of a complex built in Prague during 1945 to 1990. It has three sets of apartments (note stairways and entrances).

Commentary

For Box-wall Principle reinforced concrete, walls and ceiling/floors are made in factories into panels in sizes determined by building plans and then transported to the construction site. They are classed as mass structures because the walls are load bearing though such buildings may be mistaken for framed light-clad buildings when observed in the field.

World locations where Box Wall/ Panel Buildings are Important



Figure 136. Mass 22-1 place on building construction chart.

Mass 22-2 Elevation

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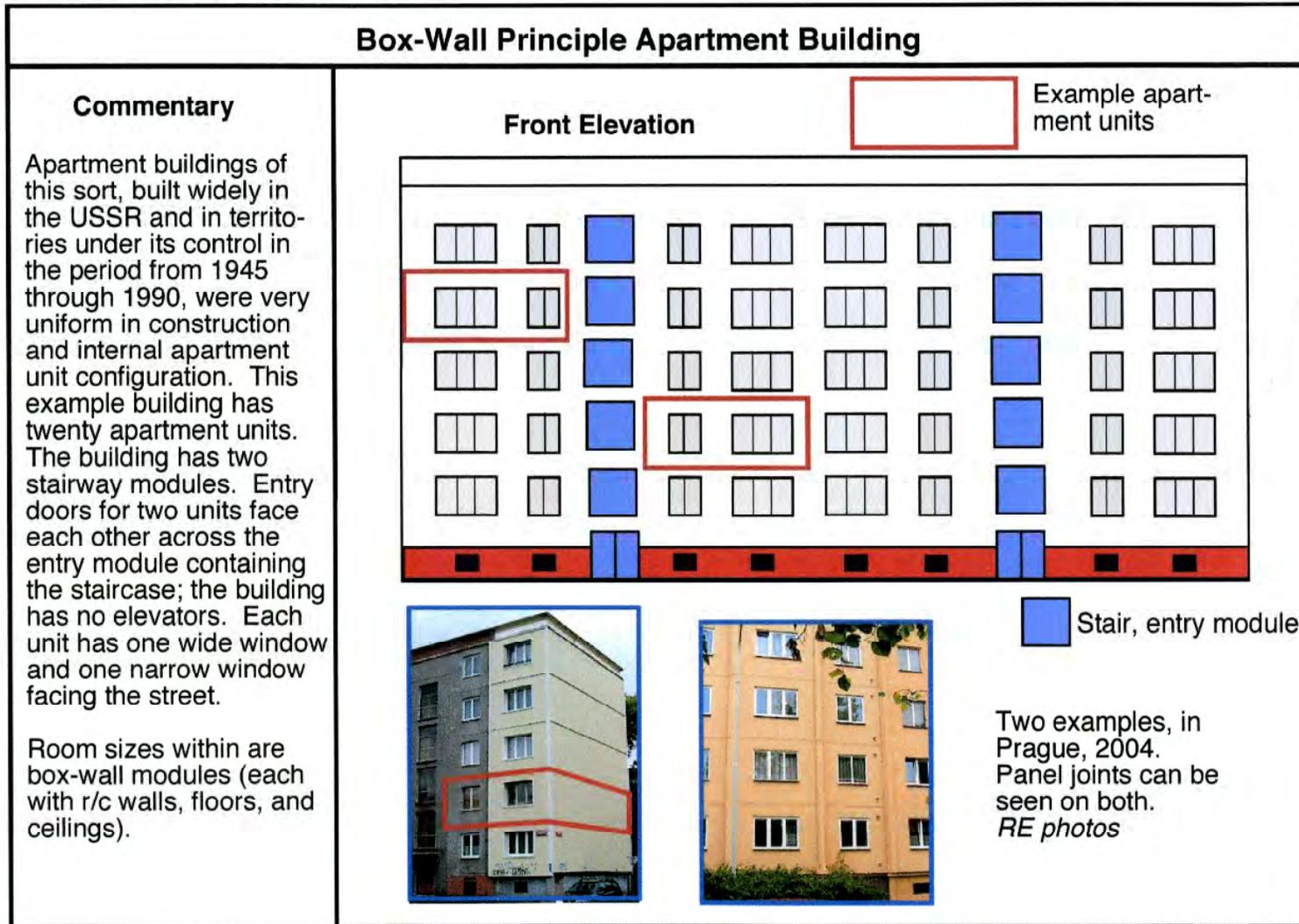


Figure 137. Mass 22-2 elevation.

Mass 22-3-a Floor Plan

Box-Wall Principle Apartment Building

Commentary

This representative three apartment segment of a multi-floor panel construction building in the former Soviet Union demonstrates several characteristics such structures had in common:

(1) the same room widths throughout is a product of using standard concrete panels.

(2) access by stairway, rather than an elevator, is indicative of the low level of the economy. This results in a distinctive floor plan.

(3) balconies are a common design feature. They have walls 1 m high, 16 cm thick.

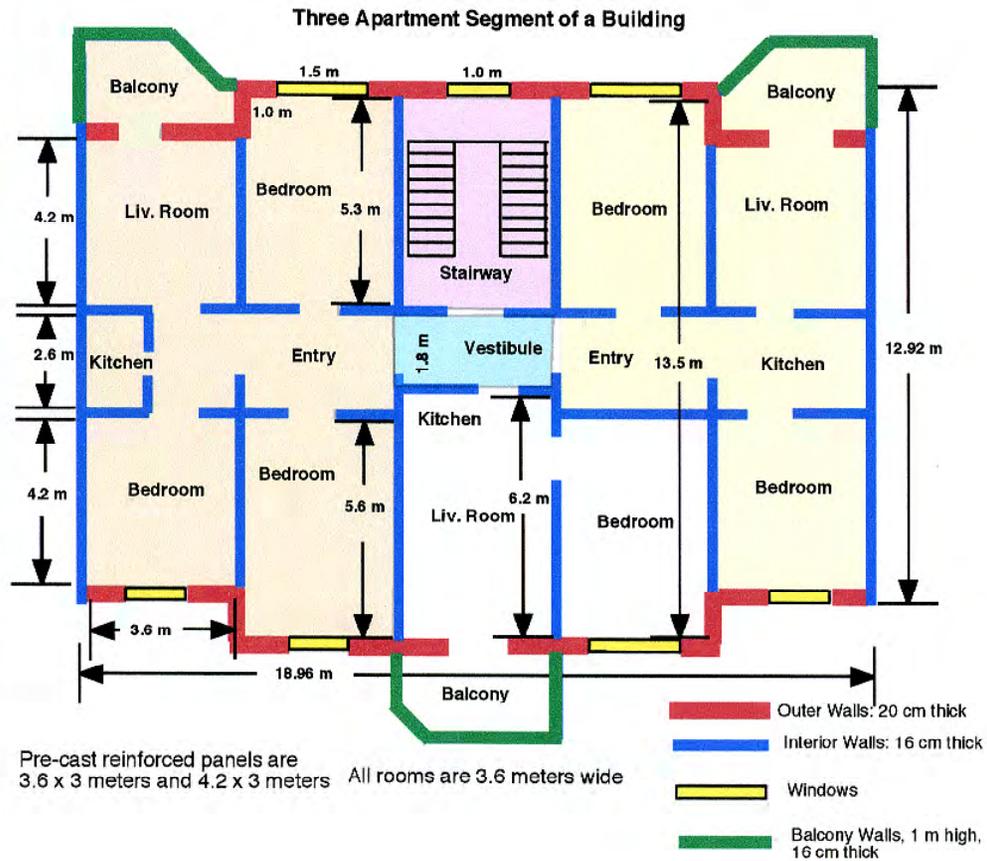
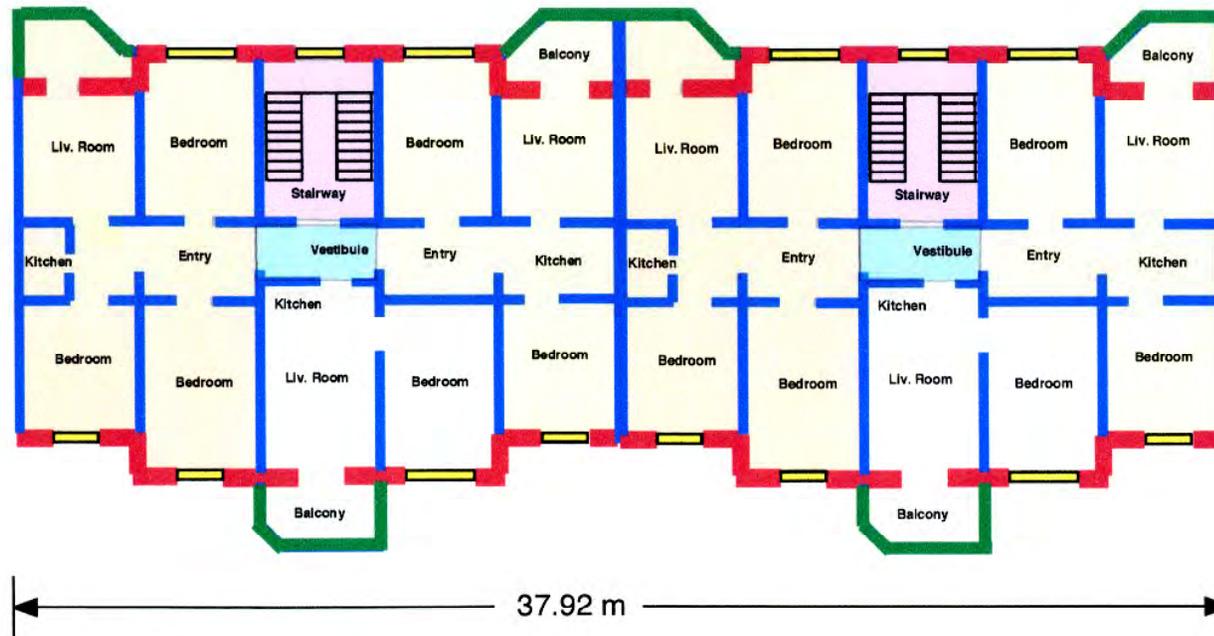


Figure 138. Mass 22-3-a floor plan.

Mass 22-3-b Floor Plan

Box-Wall Principle Apartment Building

Example of 6 Apartment Units, Upper Floors



Commentary

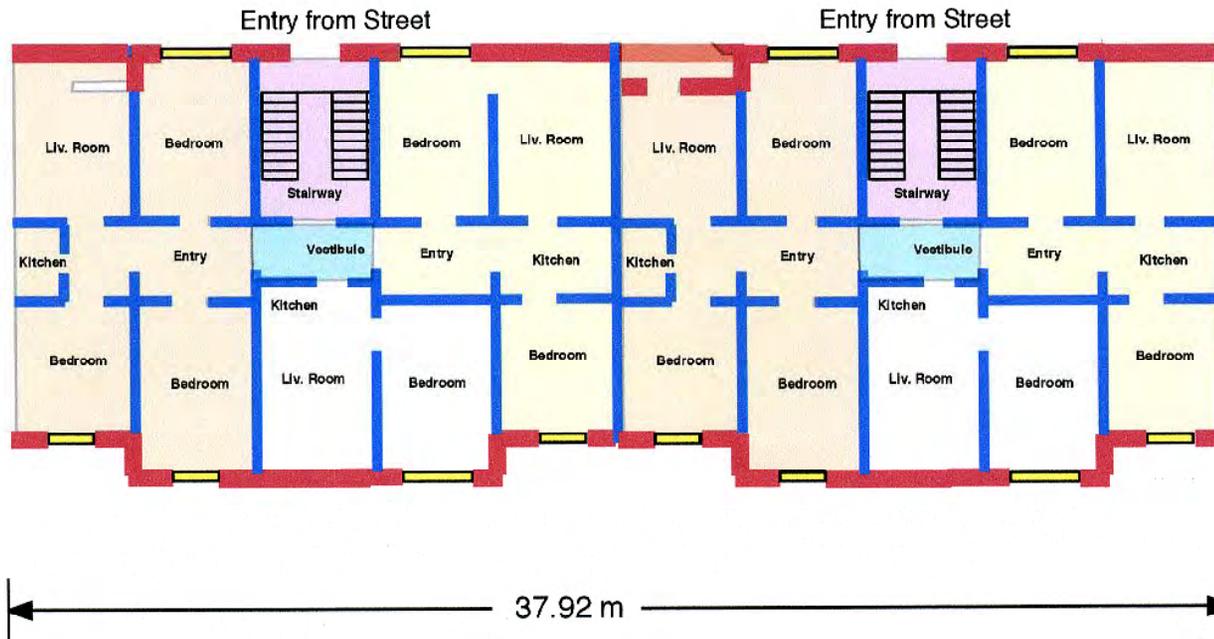
In this example, two of the modules (in Plate 22-3-a) are connected to demonstrate a common length of such structures; longer single buildings can be achieved through additional increments of three apartment modules. For dimensions, see Plate 22-3-a. Wall connecting modules are the same (16 cm thickness) as are all interior walls, indicating all were built at the same time and are unlike some brick abutted brick buildings that were built independently and where each would have an exterior wall of varying thicknesses.

Figure 139. Mass 22-3-b floor plan.

Mass 22-3-c Floor Plan

Box-Wall Principle Apartment Building

Example of 6 Apartment Units, Ground Floor



Commentary The ground floor differs from the upper floors in that it has the entrances from the street to the ground floor and upper floor apartment units and has no balconies.

Figure 140. Mass 22-3-c floor plan.

Mass 22-3-d Isometric Floor Plan, an Upper Floor

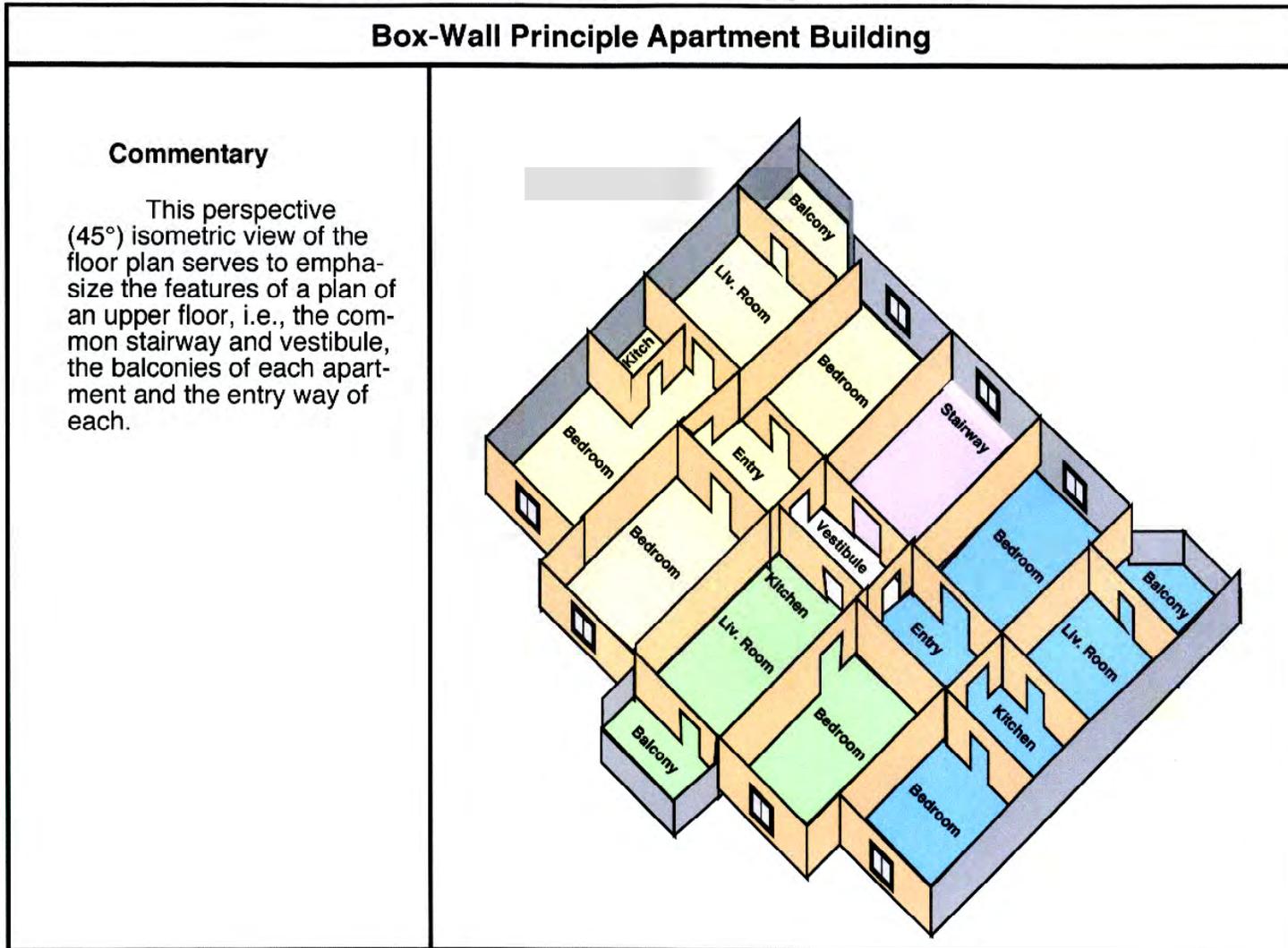


Figure 141. Mass 22-3-d isometric floor plan, an upper floor.

Mass 22-4-a Construction

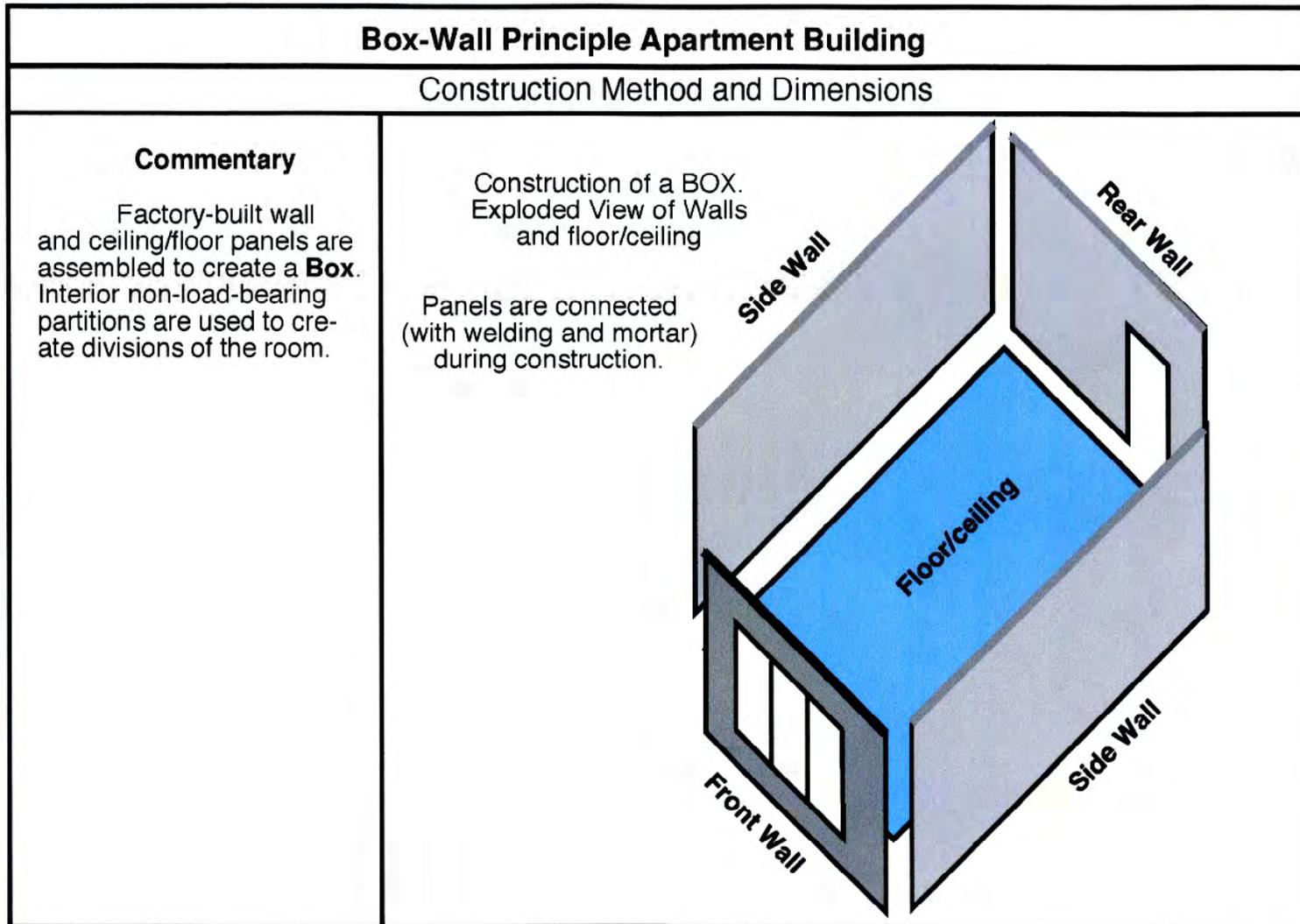


Figure 142. Mass 22-4-a construction.

Mass 22-4-b Construction

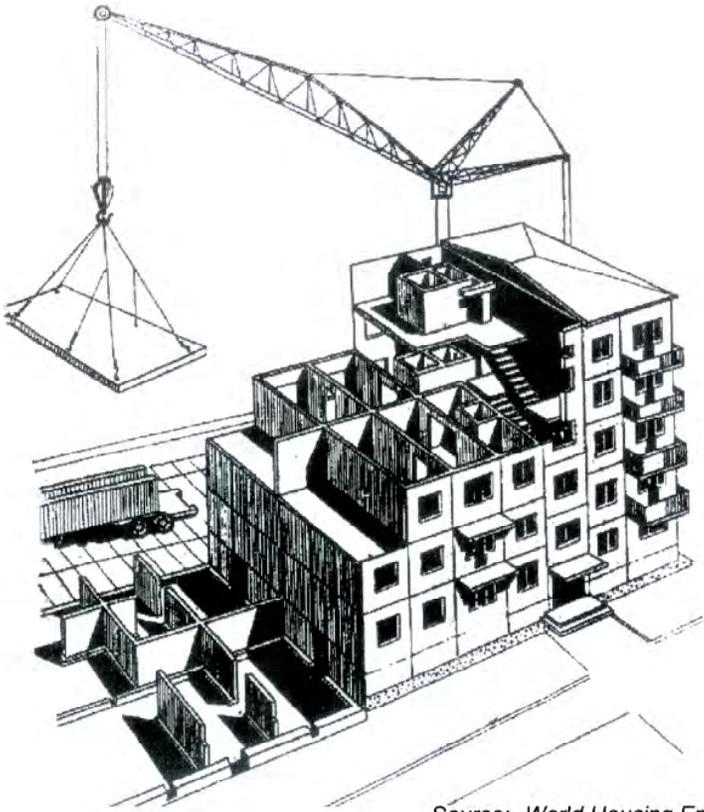
Box-Wall Principle Apartment Building	
Construction Method and Dimensions	
<p>Commentary</p> <p>Box-wall Principle construction, aka Panel Construction, is a form of Mass Construction, in that all the walls bear the load of the whole building (walls, ceilings, roofs, and live load). The exterior concrete walls are necessarily strong, being 20 centimeters thick and supported with reinforcement bars; interior walls are r/c and 16 cm thick. Panels are usually built off-site in a factory. This construction form is useful when individual "boxes" are used for rooms in apartments, or hotels, and thus where there is no desire to convert them to uses requiring large rooms, e.g., offices, such as is done with framed construction.</p> <p>Concrete compressive strength is 326 kg/cm².</p> <p>This form is found widely in Russia, former Soviet Republics, and in Eastern European former satellite countries, and is used widely for hotels and apartments worldwide.</p>	<p>Box Wall Principle, or "Panel" Construction</p>  <p>Source: <i>World Housing Encyclopedia</i></p>

Figure 143. Mass 22-4-b construction.

Mass 22-4-c Construction

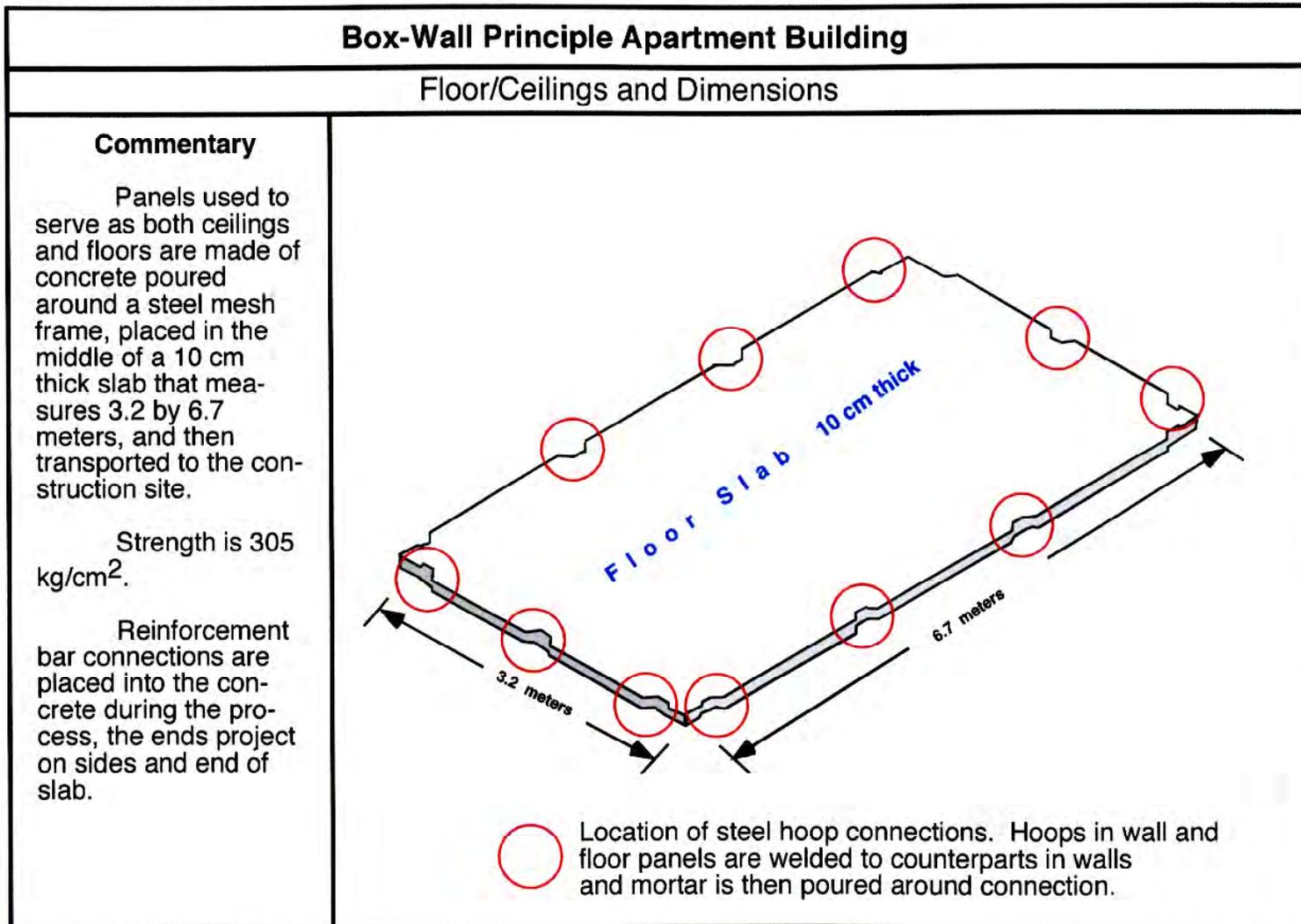


Figure 144. Mass 22-4-c construction.

Mass 22-4-d Construction

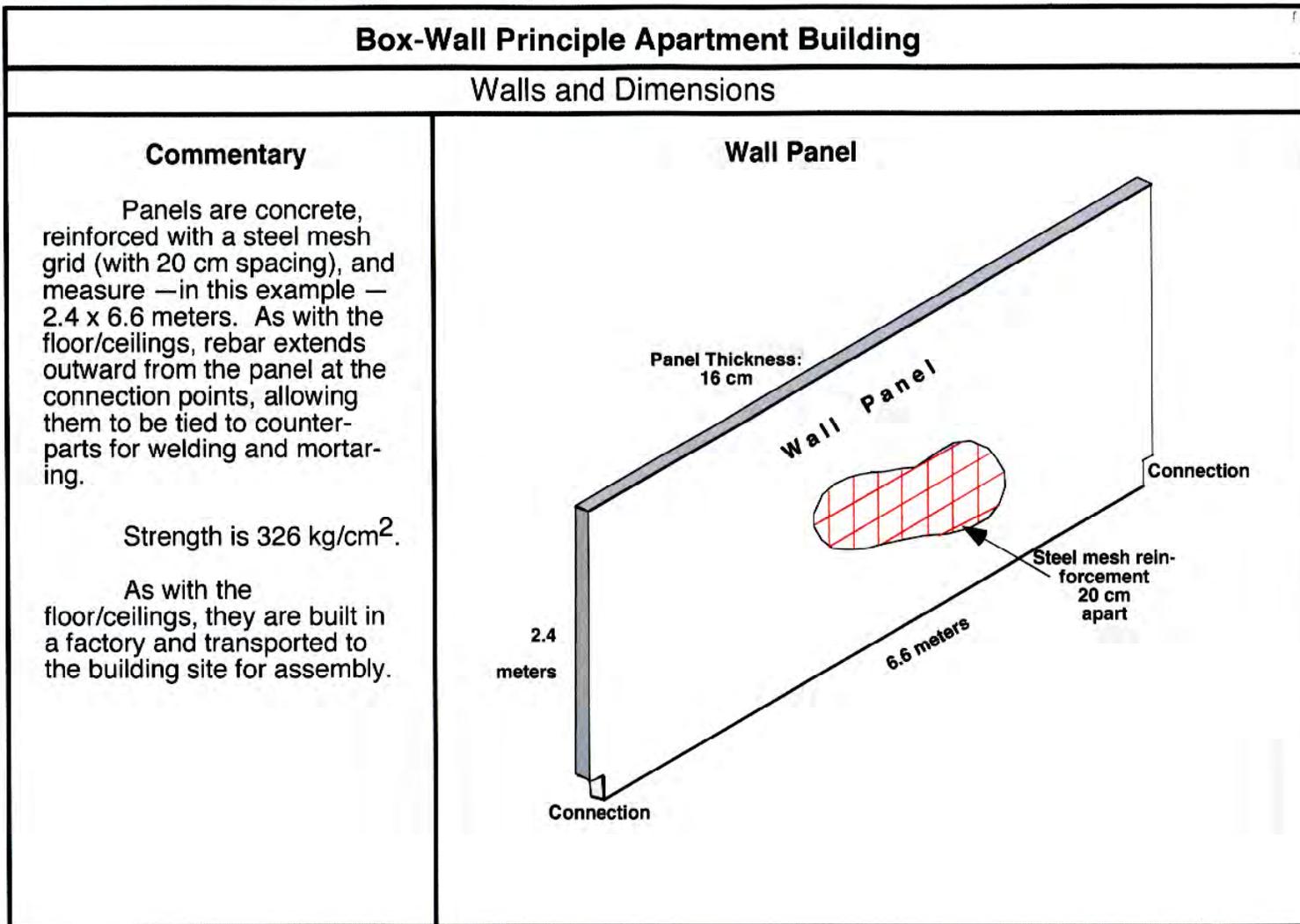


Figure 145. Mass 22-4-d construction.

Mass 22-5 Locale

Box-Wall Principle Apartment Building

Commentary

State planning is clearly manifested in apartment developments of this sort. The Soviets used this form widely and is common in countries under their domination but it is also seen in many parts of the western world, especially in Europe. The form provides shelter and open spaces between and among the buildings.

Complex of Box-Wall Apartment Buildings, Prague, Czech Republic (Typical UTZ Do2)



RE photo 2004

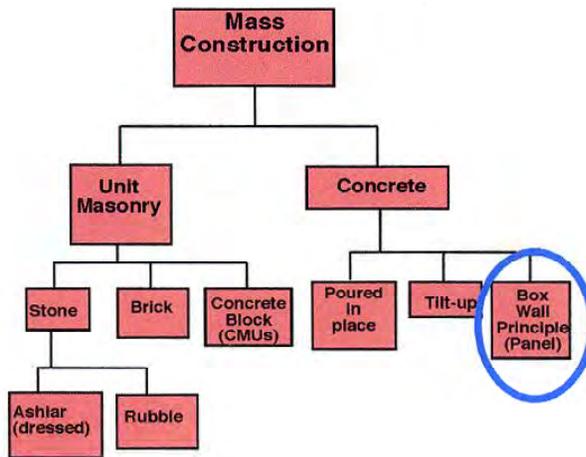
Developments of this type were replicated countless times in the Soviet Union and the Warsaw Pact to replace housing lost during WW II. Their construction followed state-directed plans expressed in buildings in the five story range (and without elevators). Entrances and stairways served a set of units on each side of each stair complex. Ventilation (see rooftops) was also by sets of units.

Figure 146. Mass 22-5 locale.

Mass 23-1 Place on Building Construction Chart

Box-Wall Principle (Panel Wall) Construction Hotel

Place on Building Construction Chart



International Example



RE photo.

This box-wall principle type of hotel structure has been replicated widely. The photo clearly shows the seven upper floors to be a series of “boxes” supporting each other. The elevator module is off-centered in order to have access from the hotel lobby. The ground floor is devoted to public room use. This form of construction is particularly well suited to hotel use considering that each guest room (plus interior bath) is a single cell and with walls that are both sound proof and not meant to be modified to serve other uses.

World locations where Box Wall/ Panel Buildings are Important

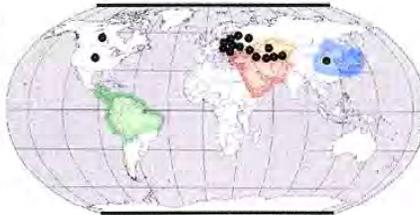


Figure 147. Mass 23-1 place on building construction chart.

Mass 23-2 Elevations

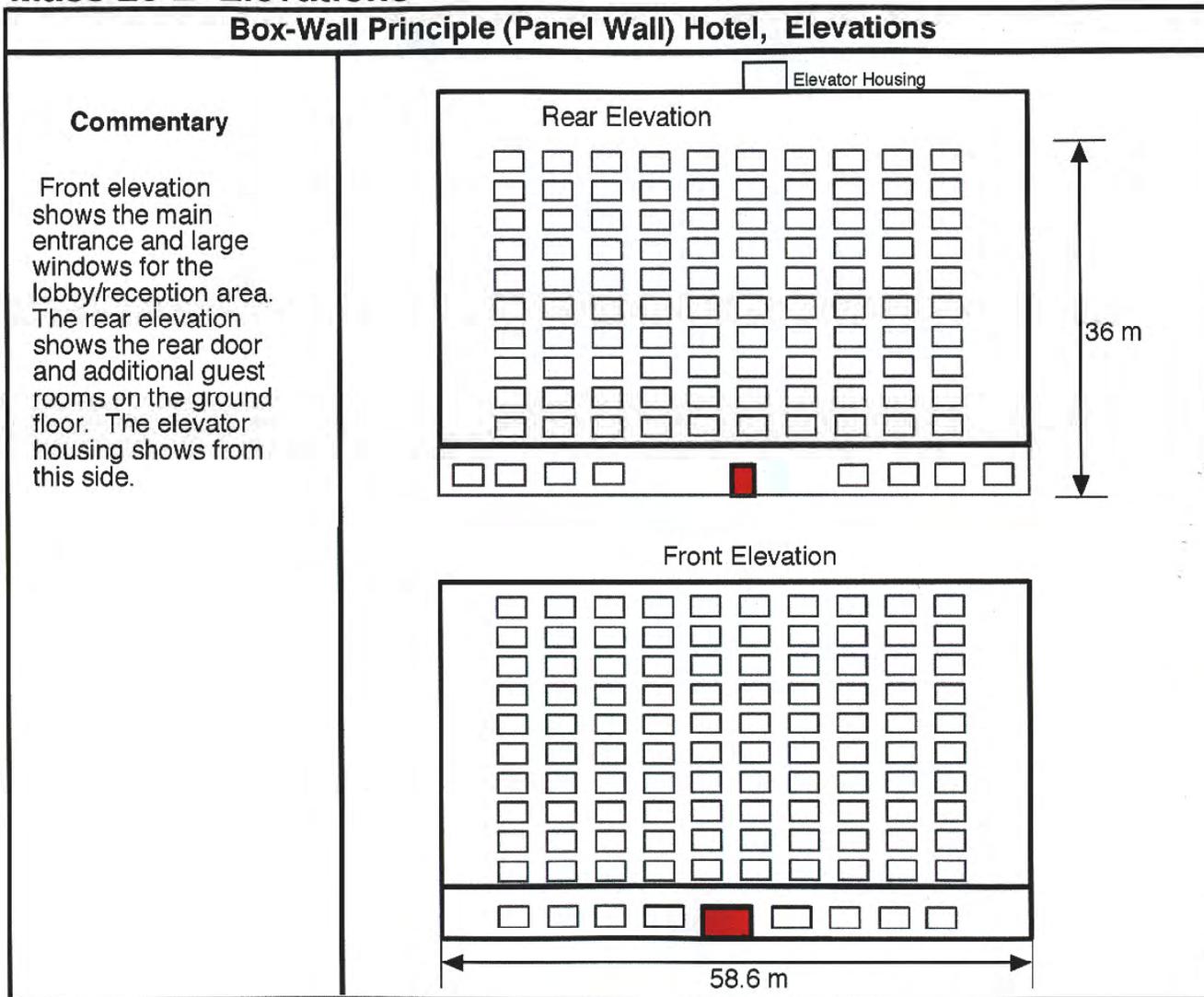


Figure 148. Mass 23-2 elevations.

Mass 23-3-a Floor Plan

Box-Wall Principle (Panel Wall) Hotel, Floor Plans

Commentary

Guest rooms are on the upper floors, plus a few on the ground floor. Public areas, the reception, lobby, services, etc. are on the ground floor.

The main entrance is in the center of the building; Other entrances are at the rear and the ends of the building.

Stairs are placed at both ends of the building.

See following plates for details on dimensions of the guest rooms.

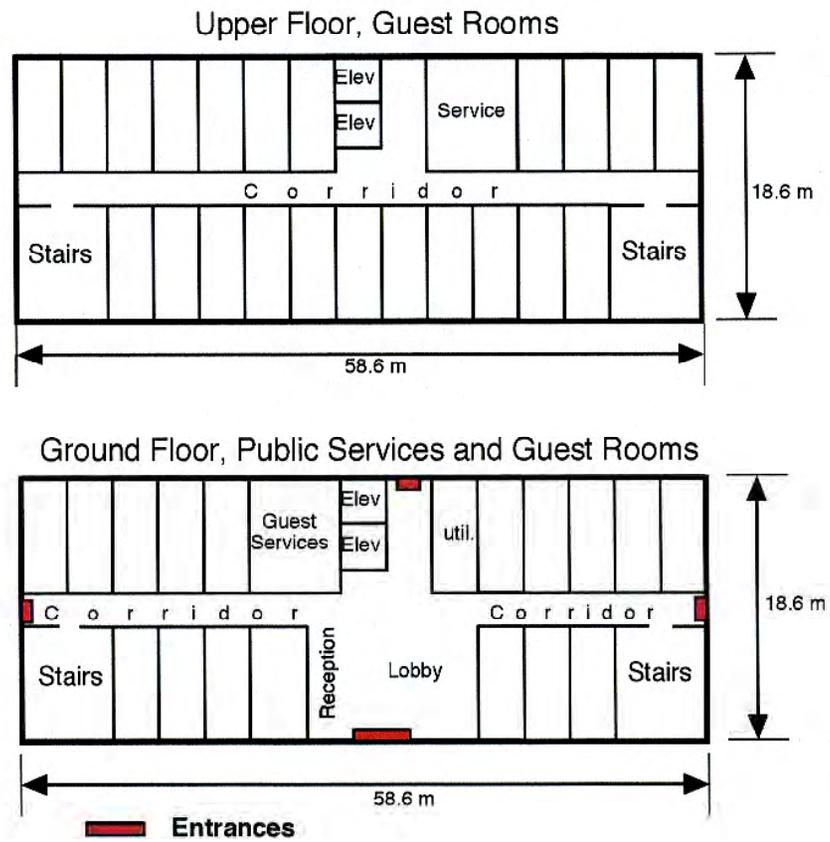


Figure 149. Mass 23-3-a floor plan.

Mass 23-3-b Floor Plan

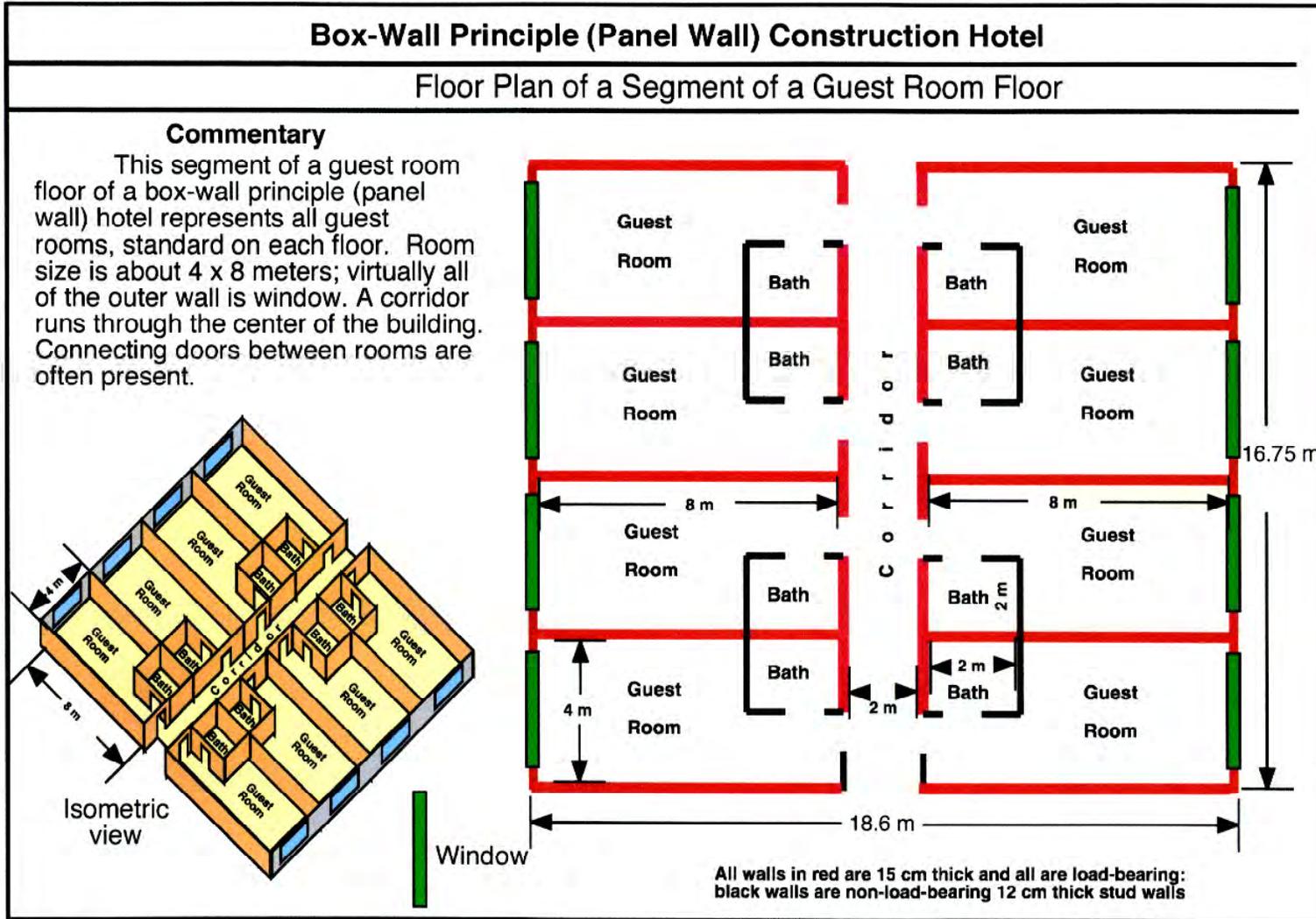


Figure 150. Mass 23-3-b floor plan.

Mass 23-4 Construction Details

Box-Wall Principle (Panel Wall) Construction Hotel

Commentary

The mass nature of construction is clear in this example. The side, bottom, top, and rear walls form a closed box of reinforced concrete (15 cm in thickness). The end wall is open, with much of its area being devoted to a large window, the only ventilation and light for each cell. Some light partition material is used for the small part of the end wall not devoted to the window.

Box-wall Building Under Construction



RE Photo

Figure 151. Mass 23-4 construction details.

Table 18. Framed urban terrain building types.

Twenty-One Urban Terrain Building Types			
Building Type	Number of Plates	Building Type Name	Building Material
Framed 1	5	Half-timbered post and lintel house	Wood framed
Framed 2	6	Half-timbered store with residence above	Wood framed
Framed 3	7	Wood-framed one-story house	Wood framed/wood
Framed 4	5	Wood-framed house with brick veneer cover	Wood framed/brick
Framed 5	5	Wood-framed store	Wood framed/wood
Framed 6	9	Steel-framed heavy-clad hotel	Steel framed
Framed 7	10	Steel-framed heavy-clad office building	Steel framed
Framed 8	5	R/C-framed light-clad apartment building	Steel/R/C framed
Framed 9	9	R/C-framed light-clad hotel	Steel/R/C framed
Framed 10	6	R/C-framed light-clad office building	Steel/R/C framed
Framed 11	7	Central pylon with light-clad steel frame office	Steel/R/C framed
Framed 12	12	R/C-framed house with brick infill walls	R/C framed with brick
Framed 13	8	R/C-framed house with terra cotta infill walls	R/C framed with terra cotta
Framed 14	8	R/C-framed CMU infill store/apartment building	R/C framed with CMU
Framed 15	5	R/C-framed with brick infill walls store/office	R/C framed with brick
Framed 16	7	R/C-framed CMU infill industrial/storage building	R/C framed with CMU
Framed 17	6	R/C-framed terra cotta infill industrial/storage	R/C framed with terra cotta
Framed 18	6	R/C-framed brick infill industrial/storage building	R/C framed with brick
Framed 19	6	R/C-framed school with brick veneer over infill	R/C framed with brick
Framed 20	5	Steel-framed light cladding industrial/storage	Steel framed with steel
Framed 21	5	Steel-framed double light cladding industrial storage	Steel framed with steel
Total plates: 142			

Note: R/C = reinforced concrete. CMU = concrete masonry unit.

Framed 1-1 Place on Building Construction Chart

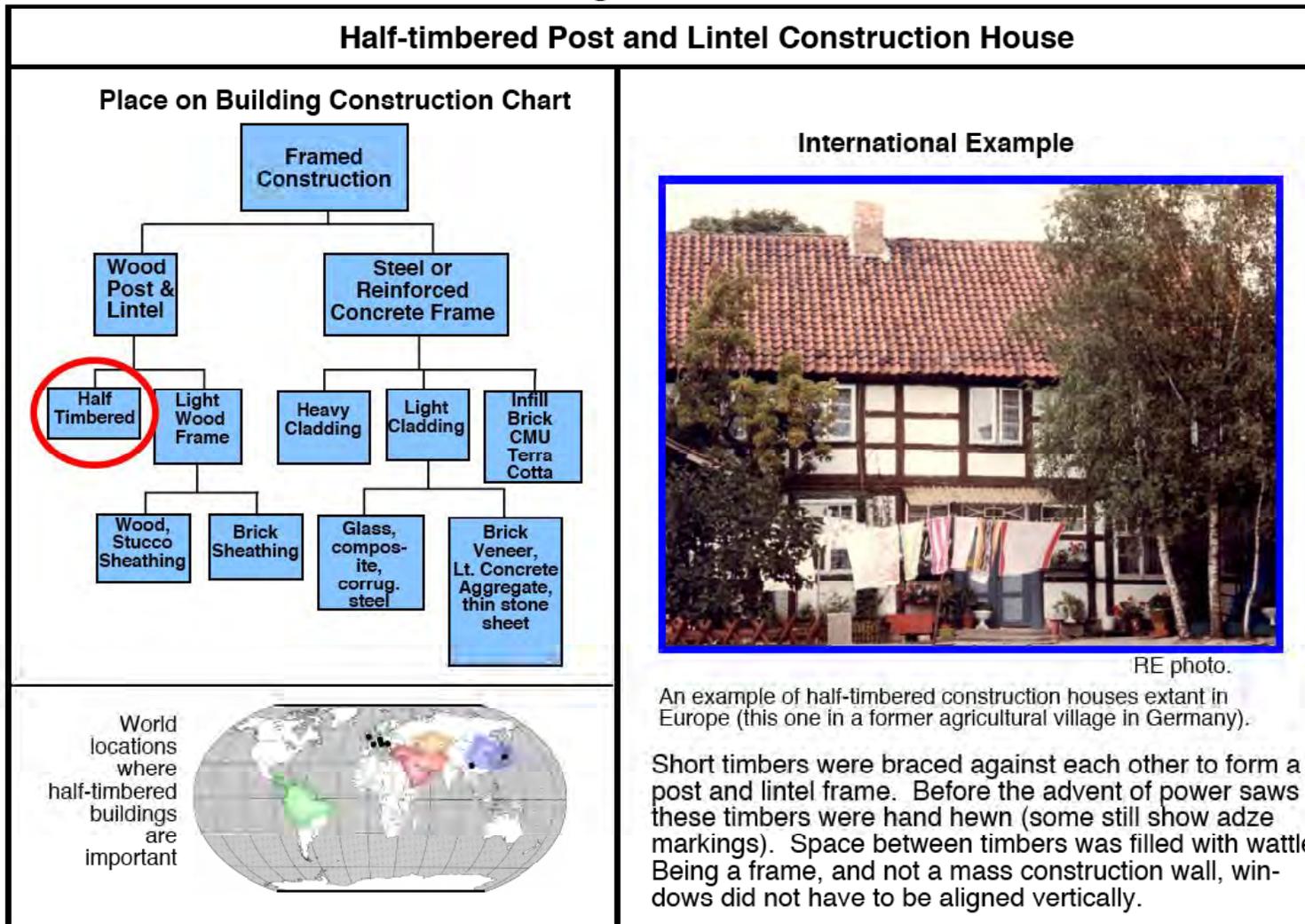


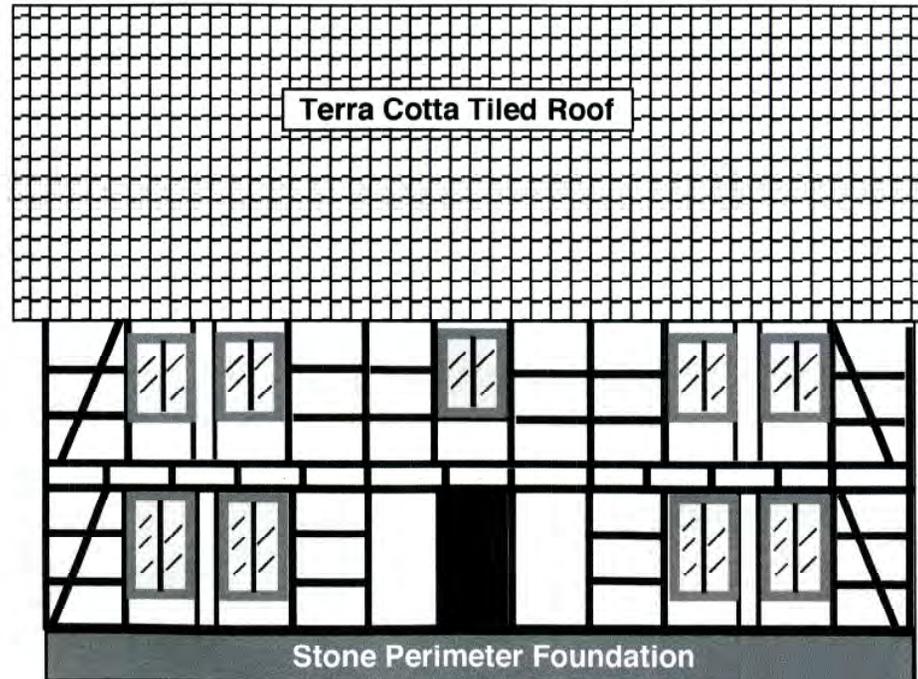
Figure 152. Framed 1-1 place on building construction chart.

Framed 1-2 Elevation and Construction Description

Half-timbered Post and Lintel Construction House

Commentary

In this type of construction, hewn timbers were used as frame members in a way similar to that employed today by reinforced concrete or steel columns and beams. Because of the difficulty of forming long columns and beams, builders — not having powered circular saws — were forced to hew square timbers from logs using a hand adze as the principal tool. Short pieces were used then to strengthen the structure; signature diagonal braces complete the image of this type of construction. Non-load-bearing fill (called wattle and daub) was placed between frame members. See plate Framed 1-4 for details.



Windows are placed between posts and beams in the same fashion as windows are placed in modern framed structures.

Figure 153. Framed 1-2 elevation and construction description.

Framed 1-4 Construction

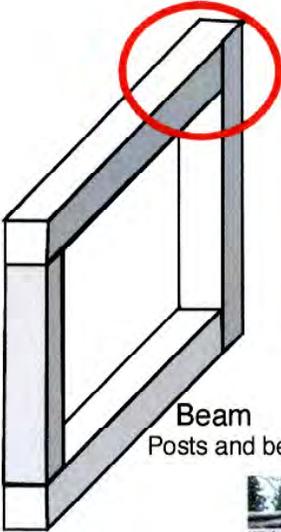
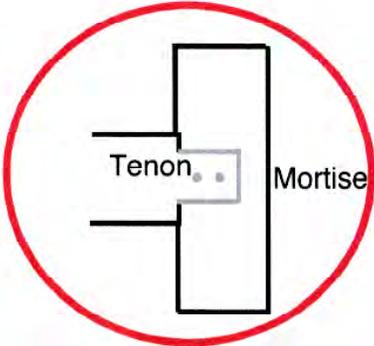
Half-timbered Post and Lintel Construction House	
Construction Details	
<p>Commentary</p> <p>Half-timbered structures employ hewn timbers in the form of posts and beams to form a skeleton frame. Connections are made by forming tenons and inserting these into mortises to form a joint. This joint is then anchored with dowels. The red circled example of one joint is representative of all joints.</p> <p>Space between the posts and beams is taken up, in a traditional fashion, with non-load-bearing wattle and daub (the wattles are wooden poles, held together with a clay daub); the surface was usually whitewashed resulting in a highly contrasting dark wood with white wall in between. The wall is a non-load-bearing infill wall, performing the same function as an infill wall between r/c or steel does in framed structures.</p>	 <p>Post</p> <p>Beam</p> <p>Posts and beams are 15 cm thick</p>  <p>Tenon</p> <p>Mortise</p>  <p>Wattle and daub infill 15 cm thick</p>

Figure 155. Framed 1-4 construction.

Framed 2-1 Place on Building Construction Chart

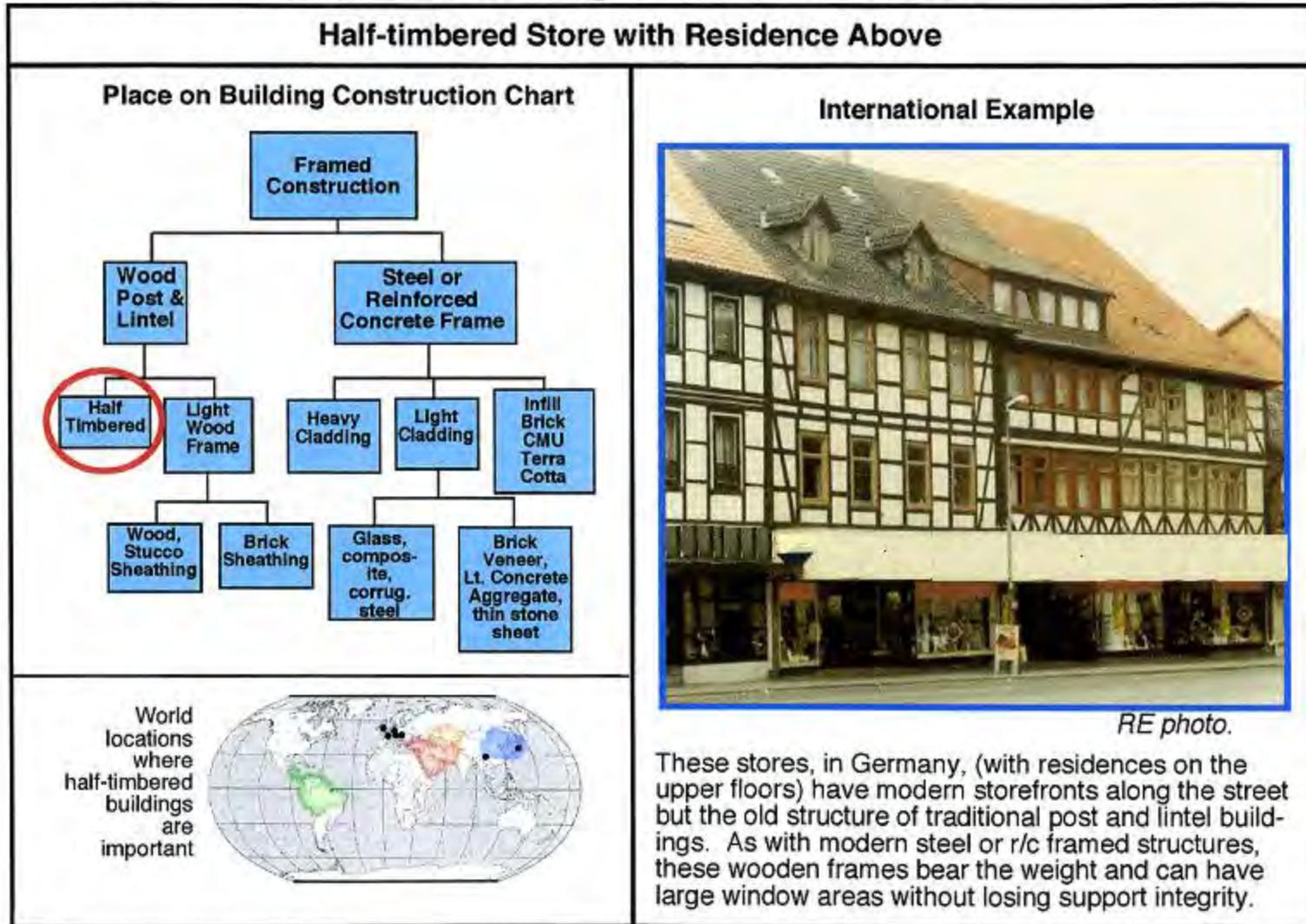


Figure 156. Framed 2-1 place on building construction chart.

Framed 2-2 Elevation and Construction Description

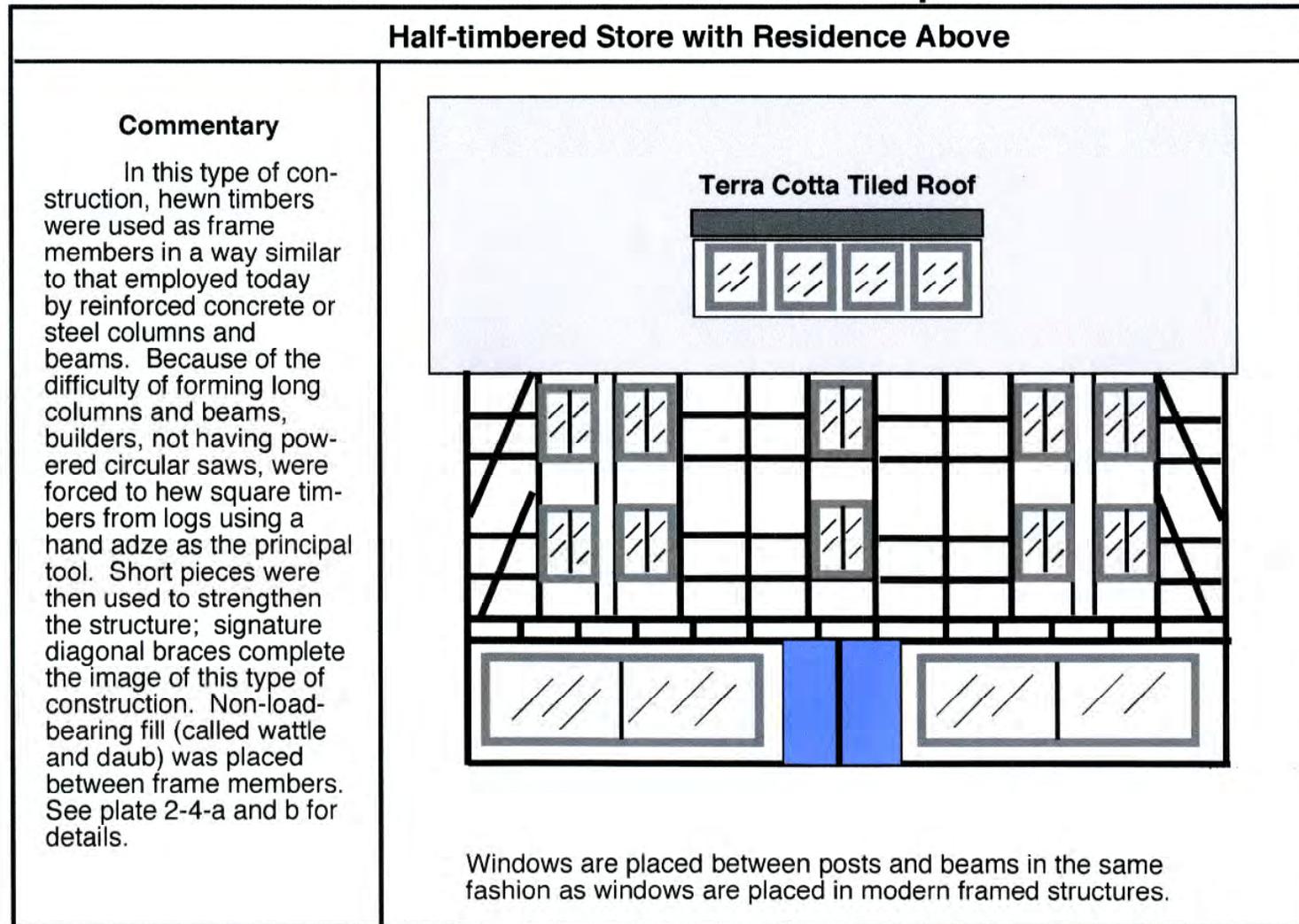


Figure 157. Framed 2-2 elevation and construction description.

Framed 2-3-a Floor Plan

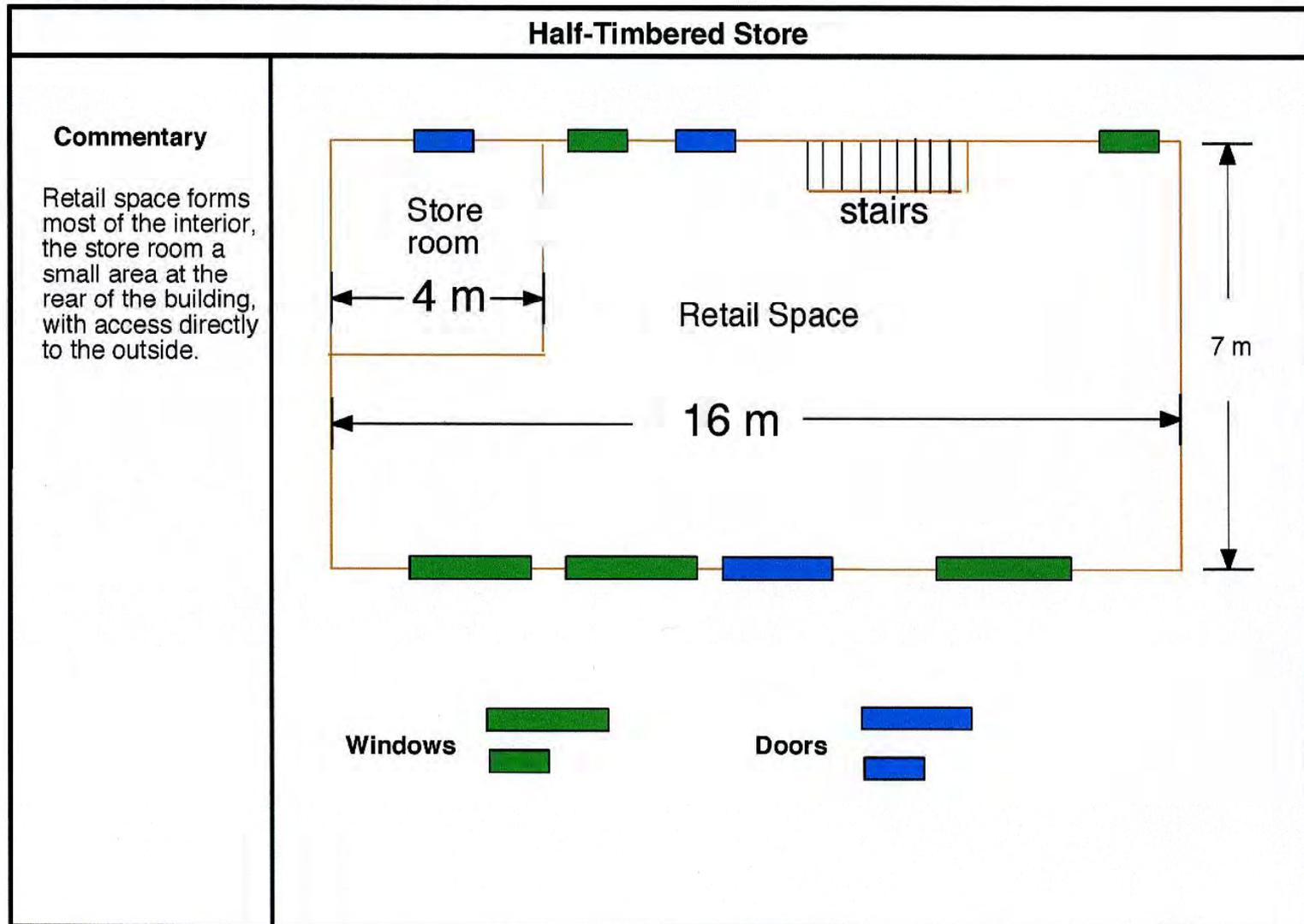


Figure 158. Framed 2-3-a floor plan.

Framed 2-4-a Construction Method

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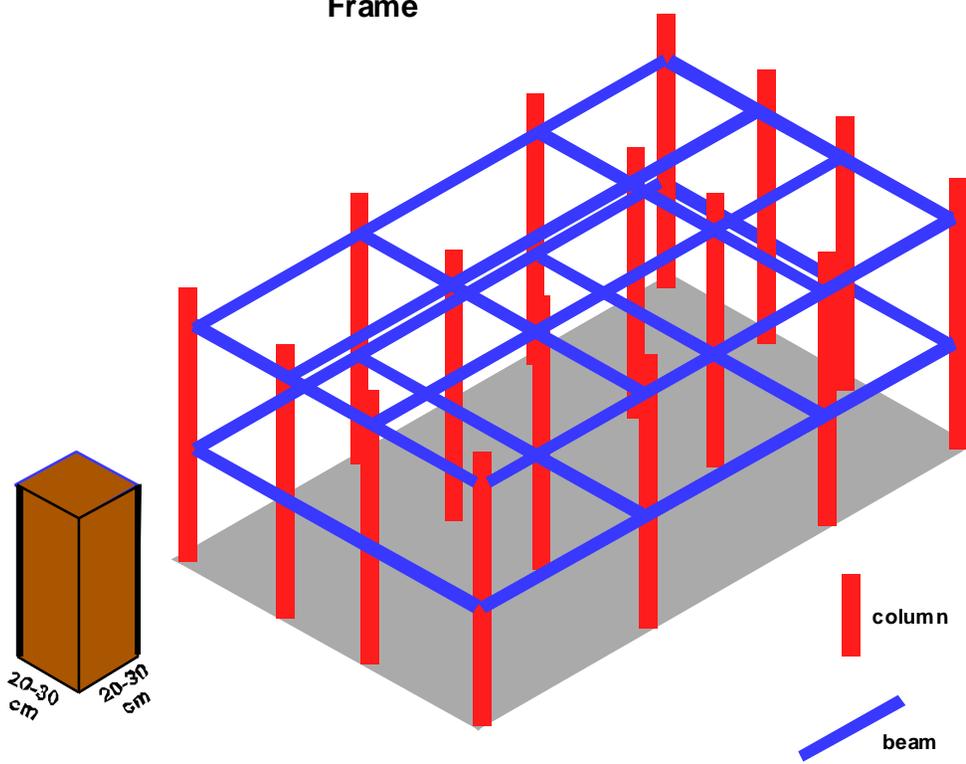
Half-timbered Store with Residence Above	
Construction Method and Dimensions	
<p>Commentary</p> <p>Half timbered buildings were the precursors to steel and r/c skeletal construction but with wooden timbers. The frame bore the loads and not the walls. Timbers were massive (20 to 30 cm on a side) hewn from single logs with adzes. Connections were made with tenons and mortises. See following plate.</p>	<p style="text-align: center;">Frame</p>  <p style="text-align: center;">Windows are placed between posts and beams in the same fashion as windows are placed in modern framed structures.</p>

Figure 159. Framed 2-4-a construction method.

Framed 2-4-b Construction Details

Half-timbered Store with Residence Above



Post and lintel house in a village in southern China. *RE photo.*



Purlins and truss of the house to the left. The vertical beam is mortised on to the purlin. *RE photo.*



Dowels fix tenon to mortise in this example in the UK. *RE photo.*

Framed 3-1 Place on Building Construction Chart

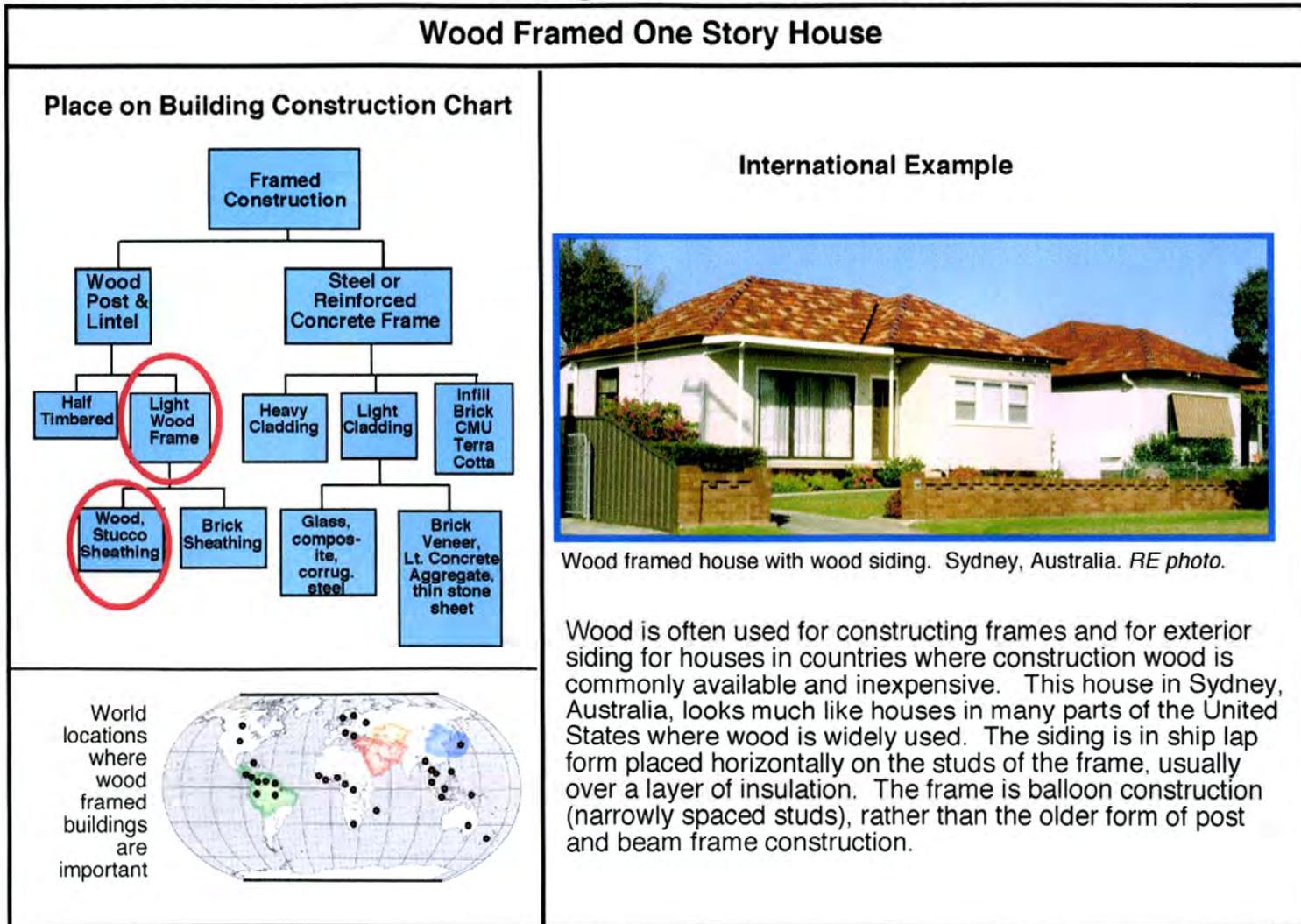


Figure 161. Framed 3-1 place on building construction chart.

Framed 3-2 Elevations

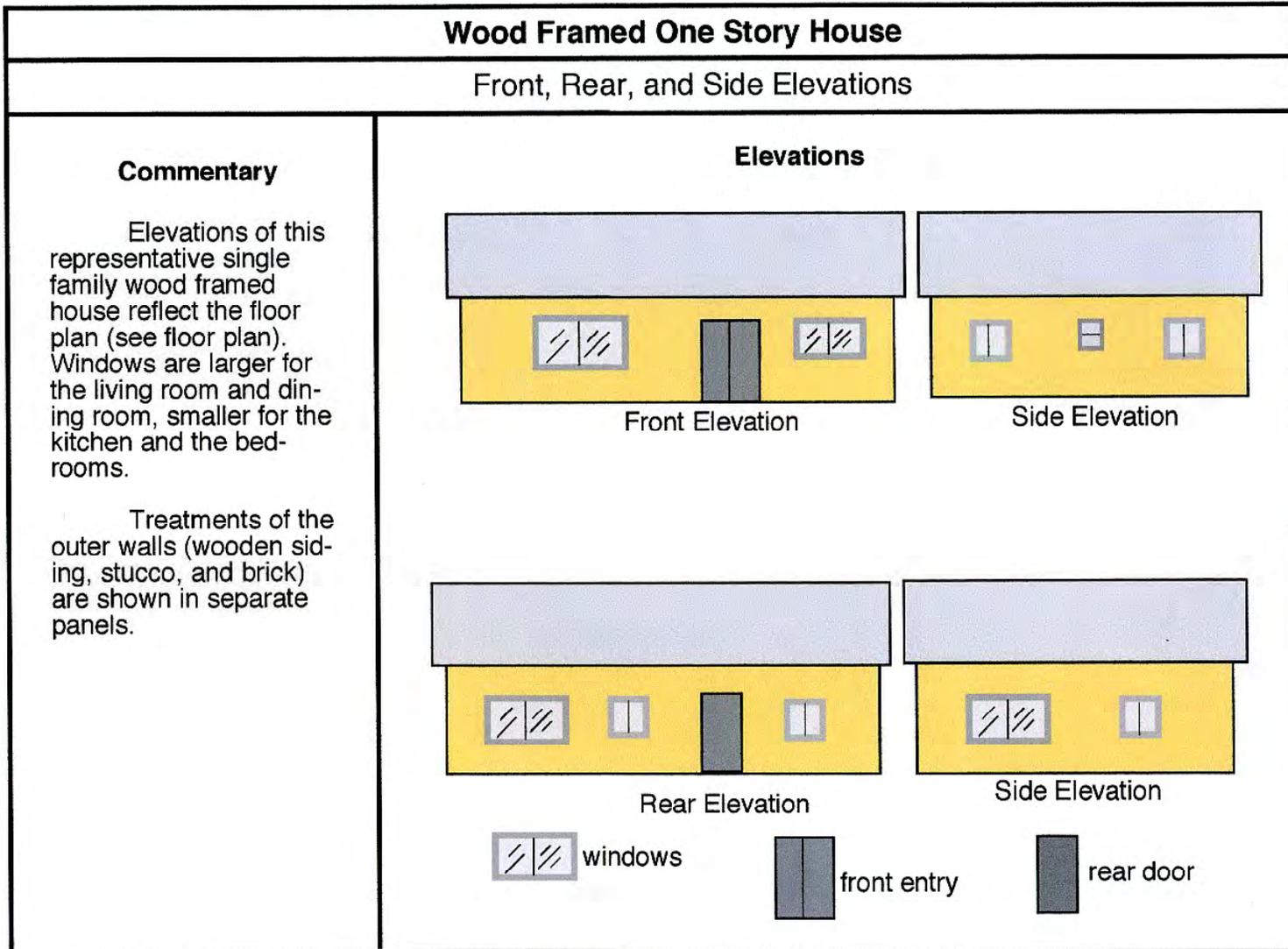


Figure 162. Framed 3-2 elevations.

Framed 3-3-a Floor Plan

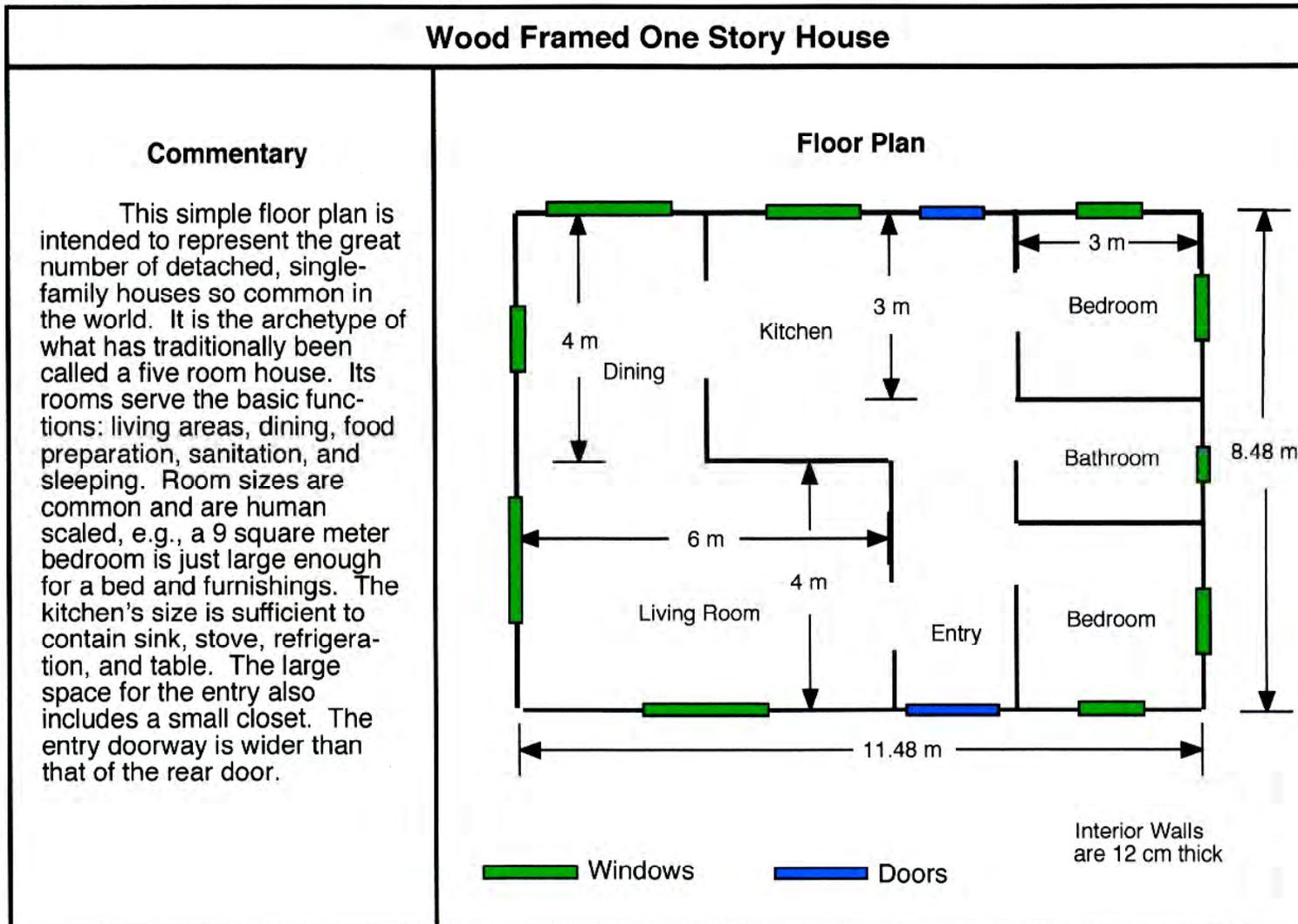


Figure 163. Framed 3-3-a floor plan.

Framed 3-4-a Construction

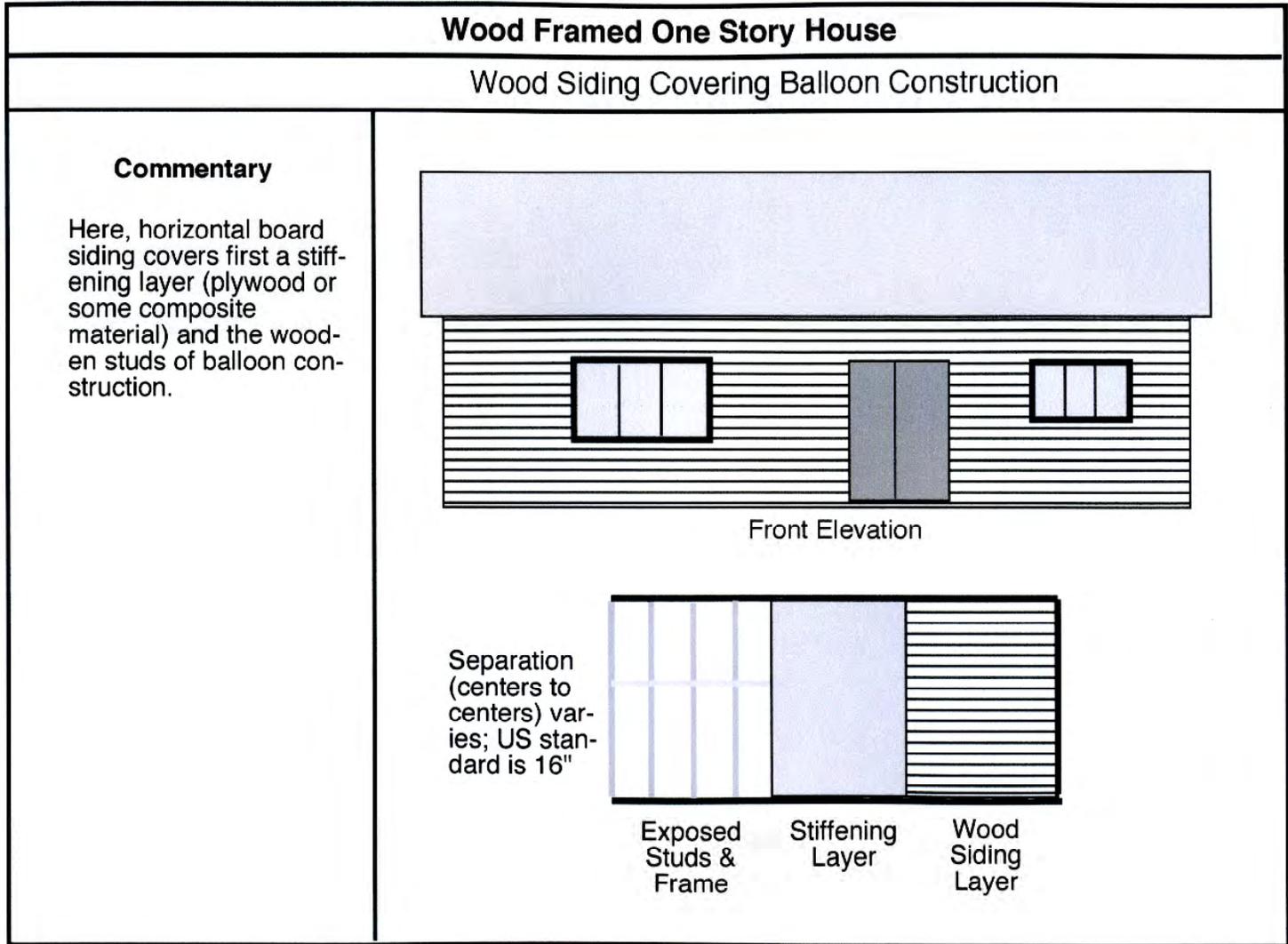


Figure 164. Framed 3-4-a construction.

Framed 3-4-b Construction

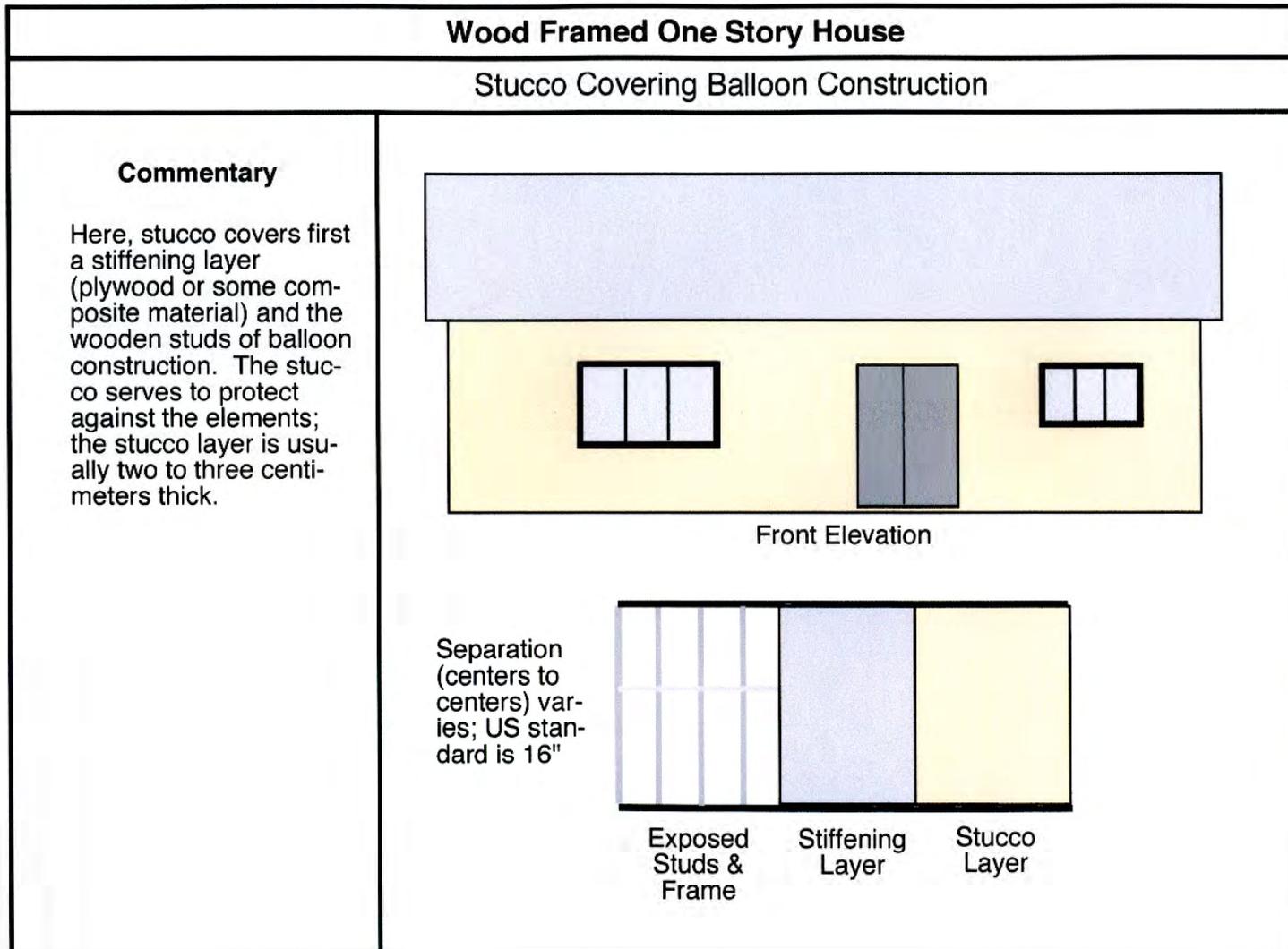


Figure 165. Framed 3-4-b construction.

Framed 3-4-c Construction

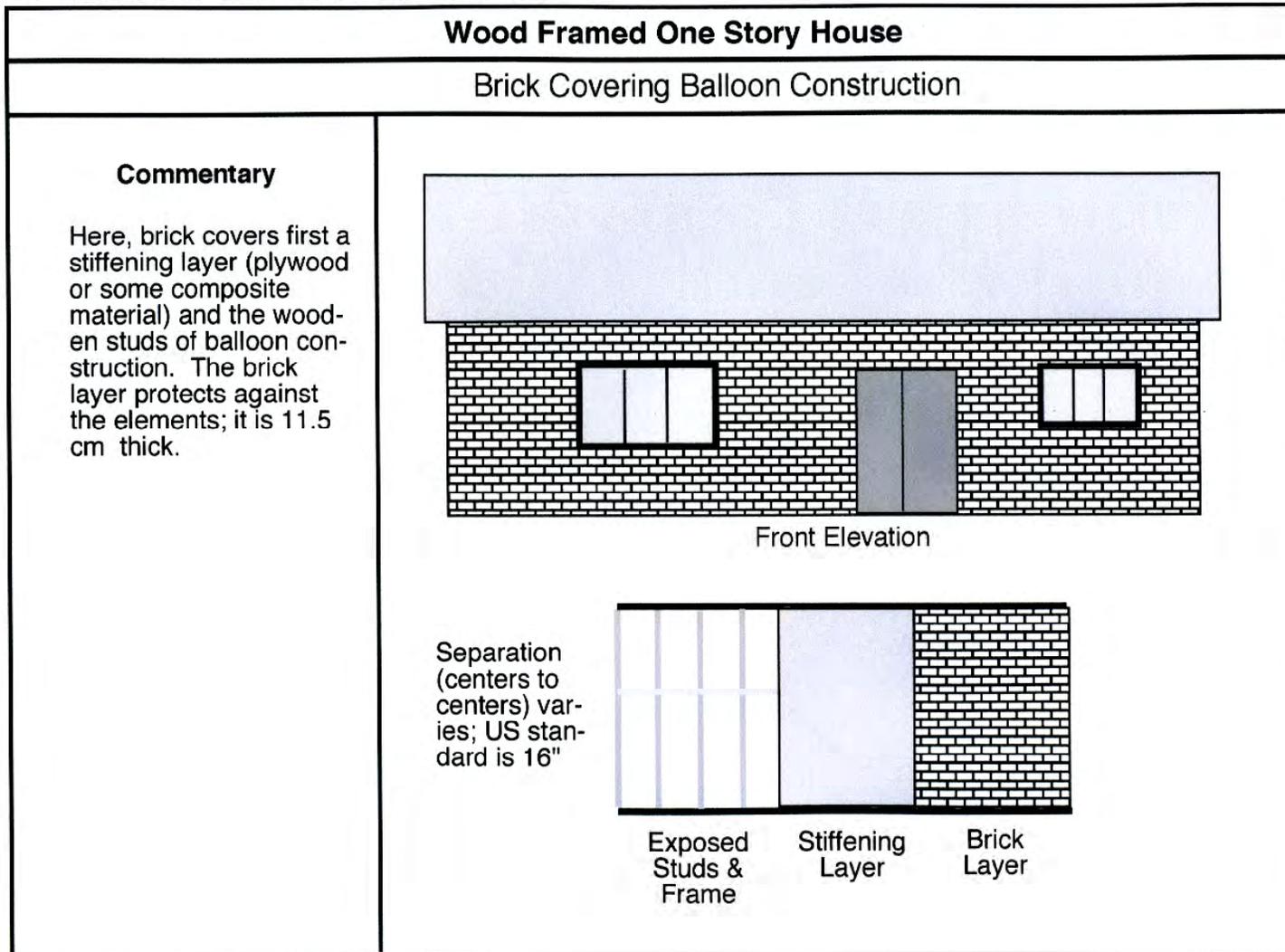
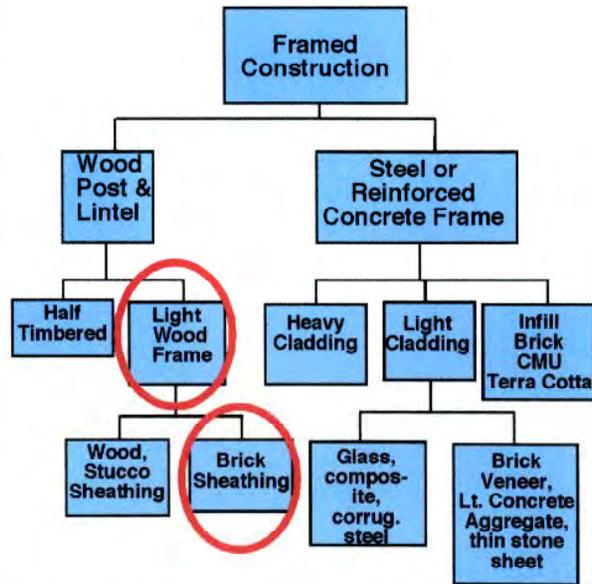


Figure 166. Framed 3-4-c construction.

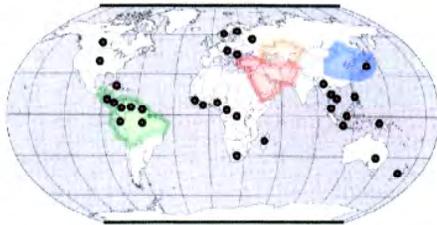
Framed 4-1 Place on Building Construction Chart

Wood-framed House with Brick Veneer Cover

Place on Building Construction Chart



World locations where wood framed buildings are important



International Example



Partially brick-veneered wood framed house, in New Zealand.

RE Photo

A common practice with wood-framed structures is to place a non-load-bearing brick sheathing on all or a part of an exterior wall. As in this example, if only a partial cover of bricks is used, they will be on the ground floor only, following the tradition of a building having a strong foundation (pediment).

Figure 167. Framed 4-1 place on building construction chart.

Framed 4-2 Elevations

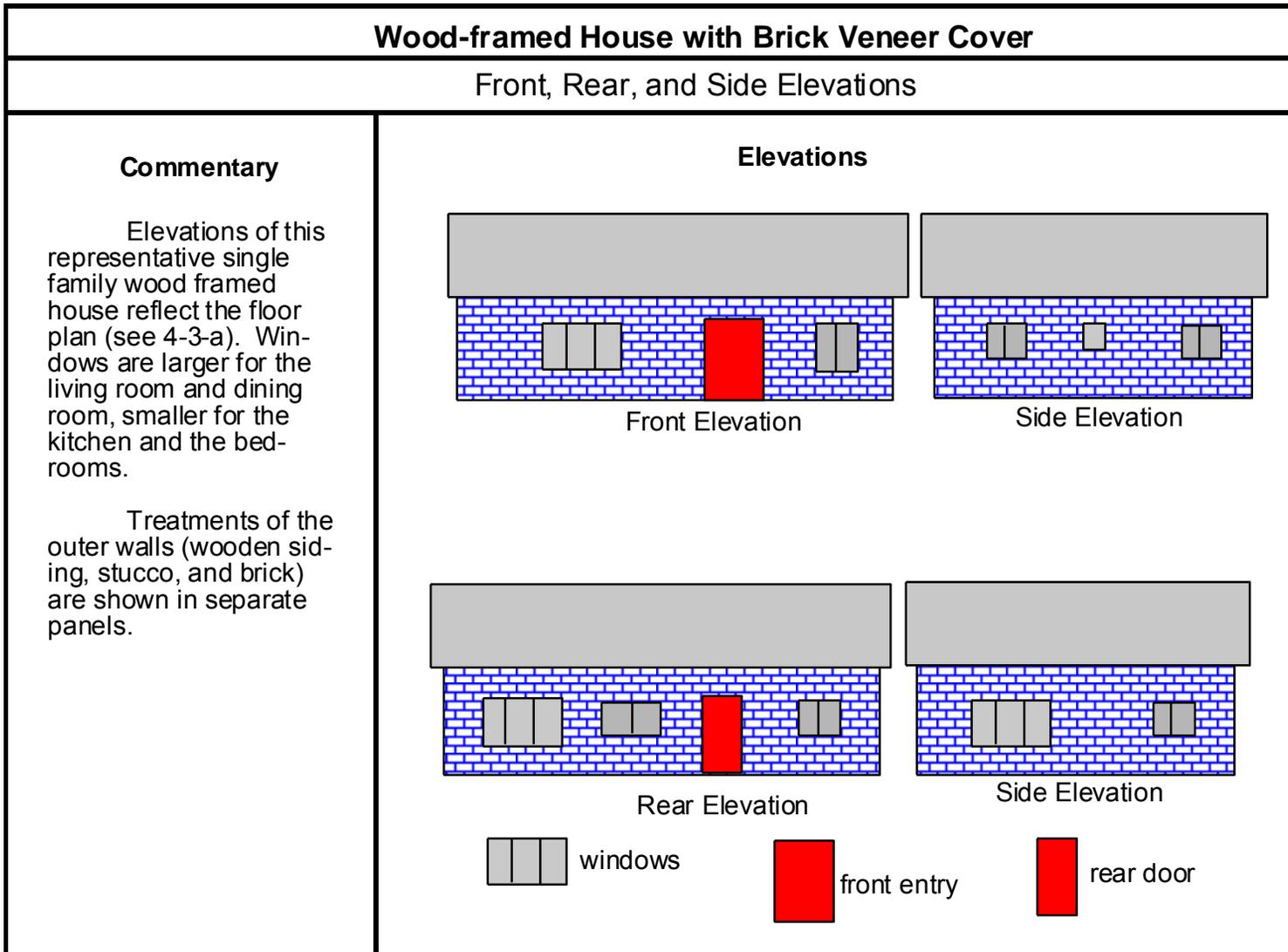


Figure 168. Framed 4-2 elevations.

Framed 4-3-a Floor Plan

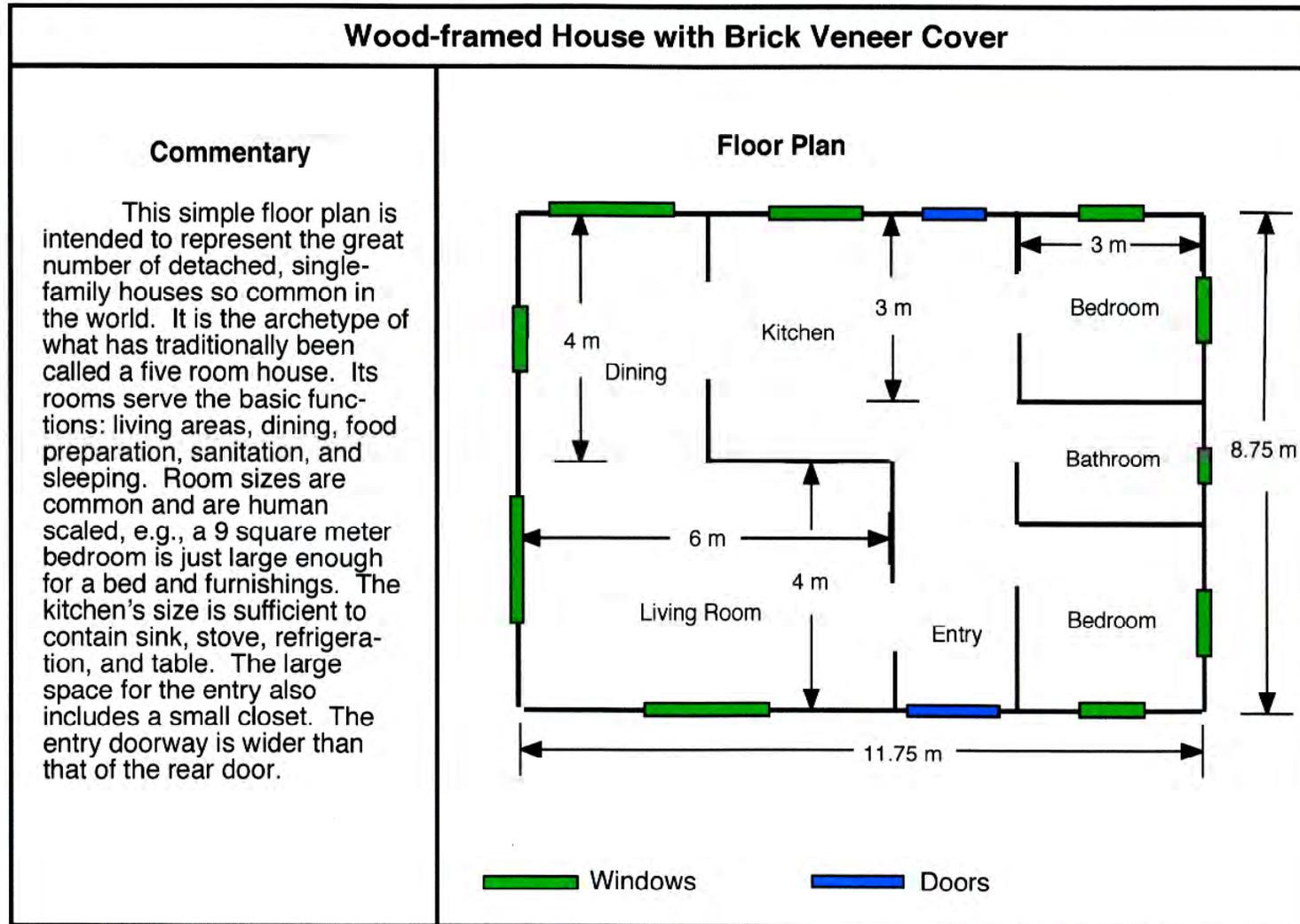


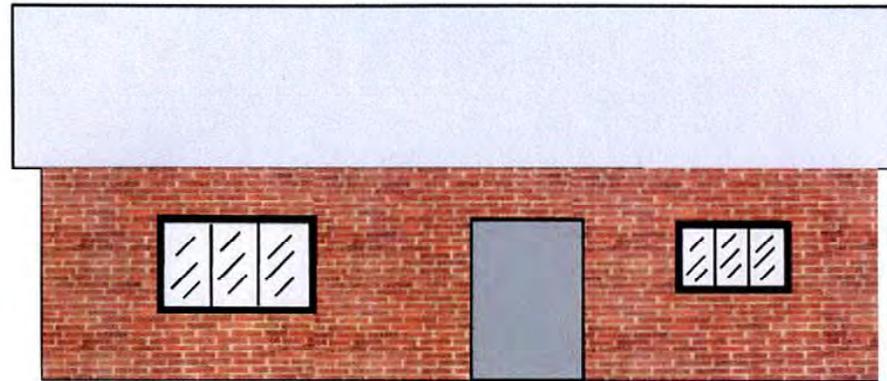
Figure 169. Framed 4-3-a floor plan.

Framed 4-4 Construction

Wood-framed House with Brick Veneer Cover

Commentary

Here, a brick layer covers first a stiffening layer (plywood or some composite material) and the wooden studs of balloon construction. The brick layer serves to protect against the elements. Exposed are the sides of stretchers, laid in what is called a facing pattern. The brick segment of the wall is 11.5 cm thick. Studs and stiffening (1 cm) add 12 cm for a total of 24 cm. This includes a 10 cm air space between the studs and a 1 cm covering on the interior side of the wall.



Front Elevation

A gap (2 cm or so) often separates the stiffening layer from the brick and is connected with "brick ties" to achieve ventilation and prevent water build-up.

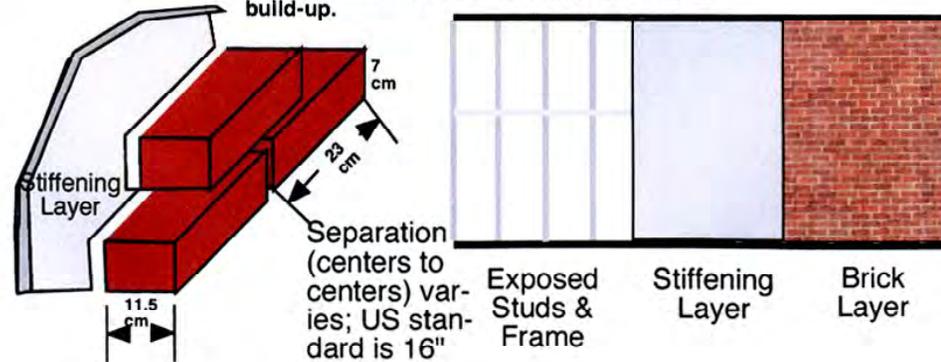


Figure 170. Framed 4-4 construction.

Framed 5-1 Place on Building Construction Chart

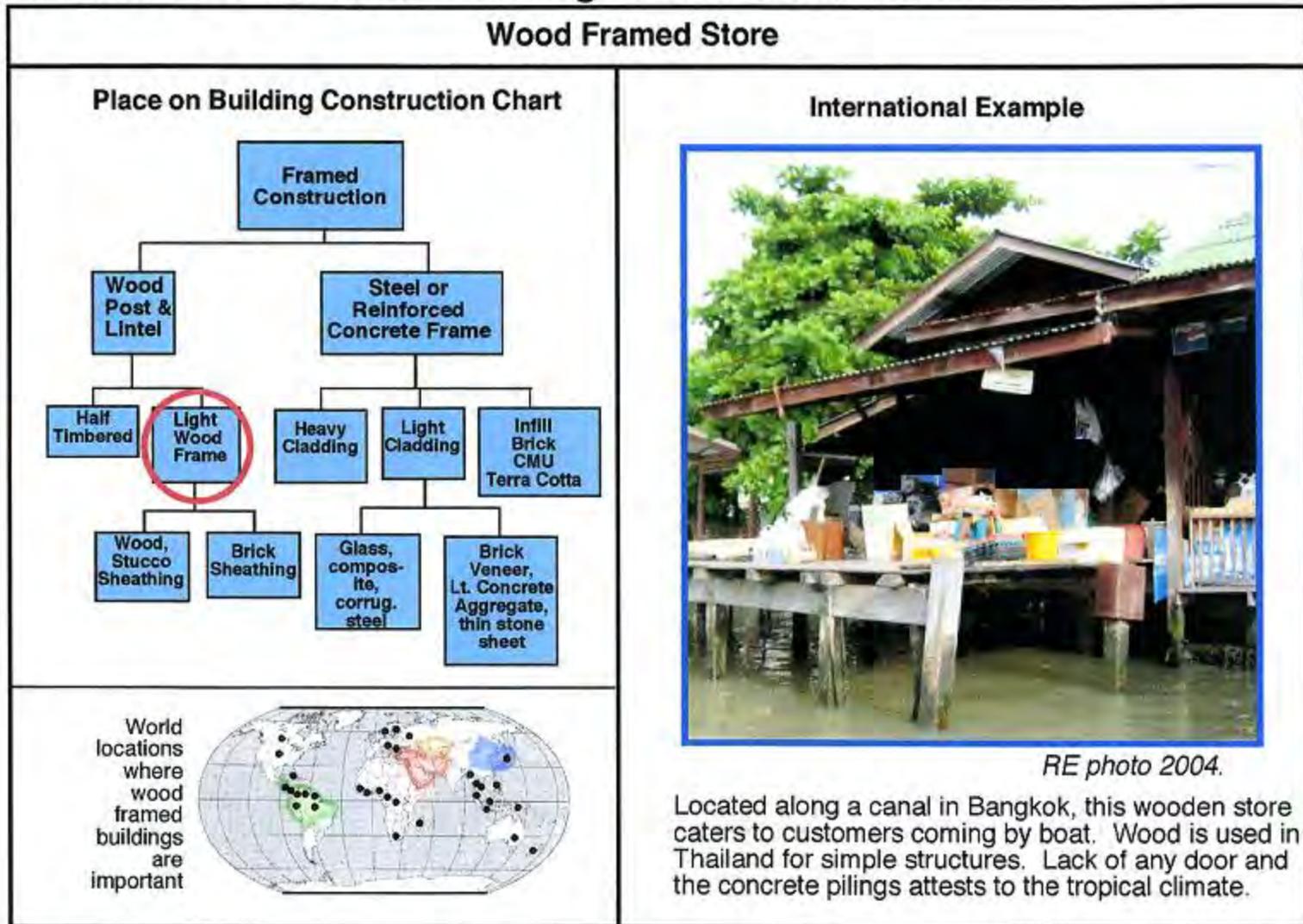


Figure 171. Framed 5-1 place on building construction chart.

Framed 5-2: Elevations

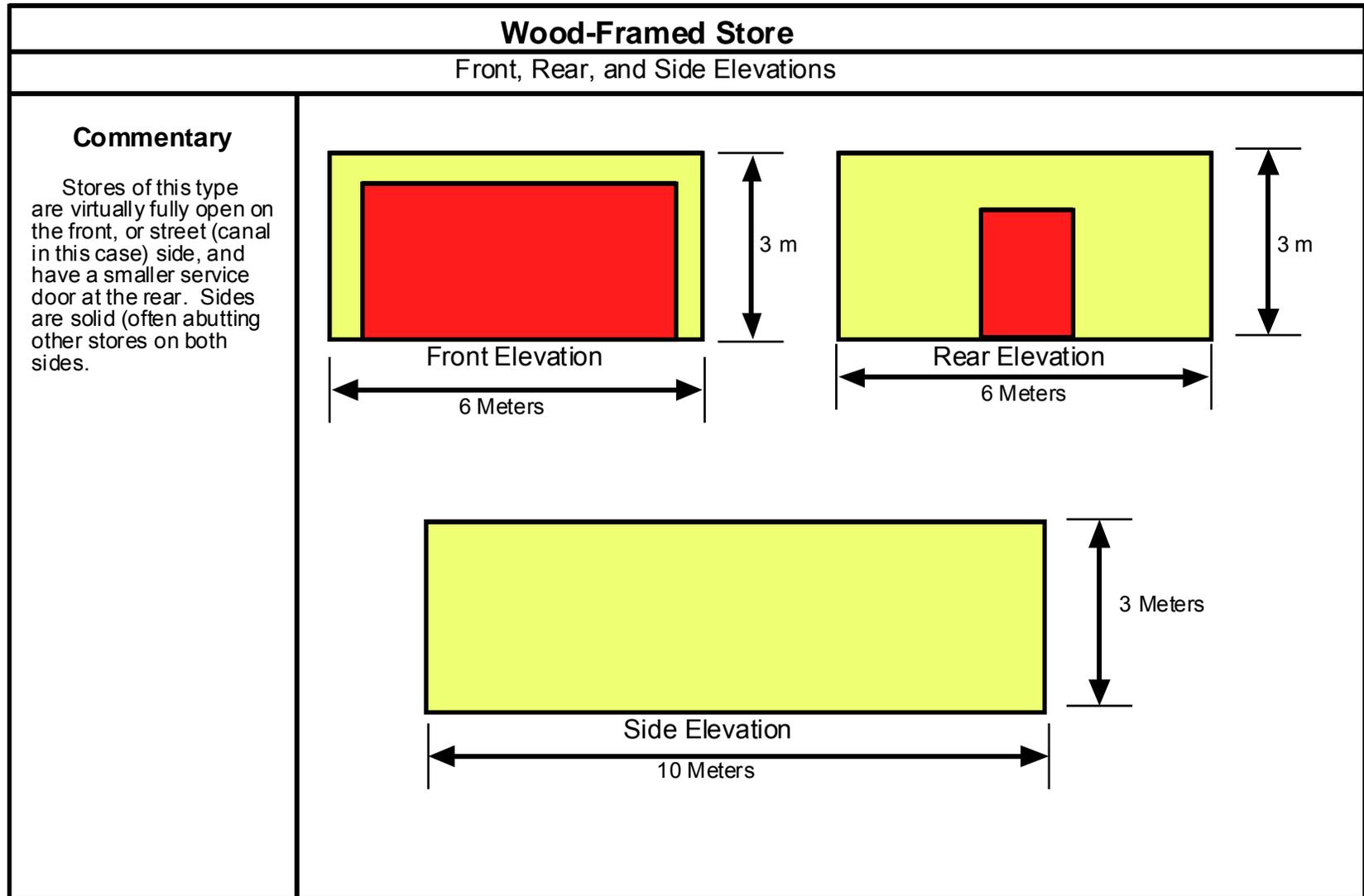


Figure 172. Framed 5-2 elevations.

Framed 5-3-a Floor Plan

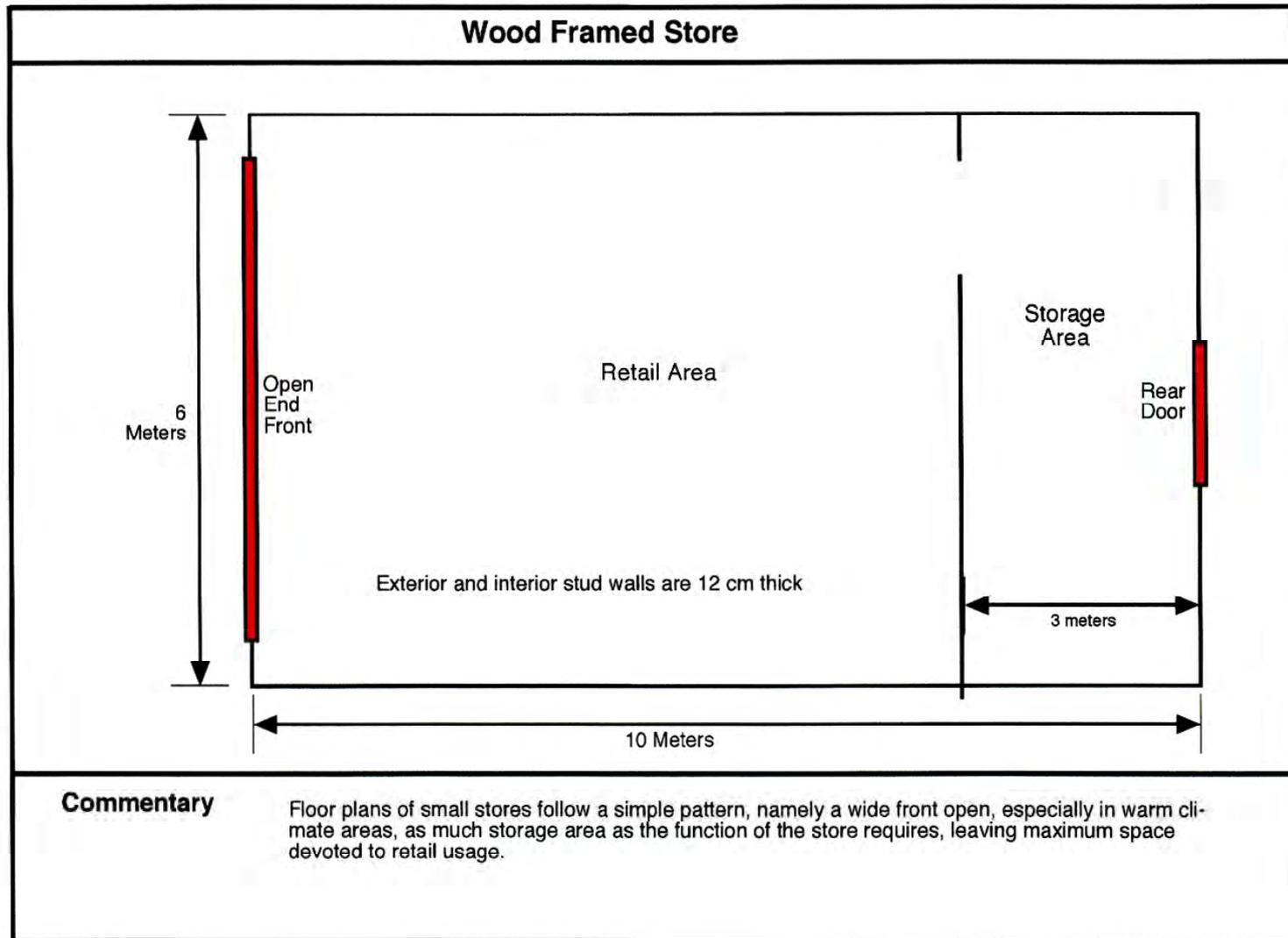


Figure 173. Framed 5-3-a floor plan.

Framed 5-4 Construction Method

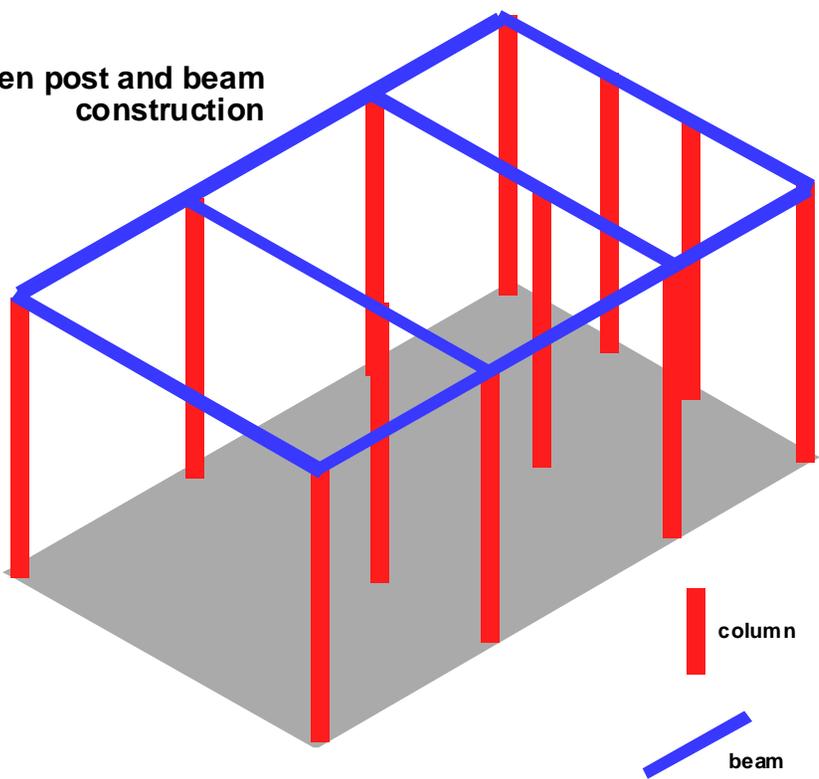
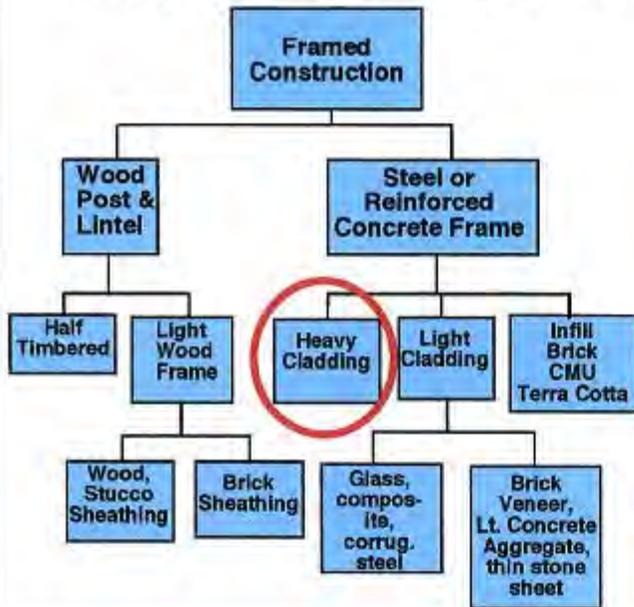
Light Wood-framed Store	
	Construction Method and Dimensions
<p>Commentary</p> <p>This store uses the simplest form of wood frame. It is sufficient in a tropical environment where roof load is light and many walls are left open.</p>	<p>Simple wooden post and beam construction</p>  <p>Columns and beams are 15 cm x 15 cm</p>

Figure 174. Framed 5-4 construction method.

Framed 6-1 Place on Building Construction Chart

Steel-framed, Heavy Clad Hotel

Place on Building Construction Chart



International Example



RE photo, 2004

A steel framed heavy-clad hotel in Kowloon (Hong Kong), built in the early part of the twentieth century, is a good example of the genre. It has a *pediment* on the ground floor with the usual shops, the *shaft* contains services on what the British refer to as the First Floor, guest rooms on the next four floors, and a *capital*, the top floor with suites and meeting rooms. The hotel's modern framed light-clad addition lies at the rear.

World locations where Steel Framed Heavy clad Buildings are important

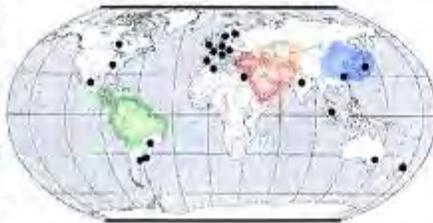


Figure 175. Framed 6-1 place on building construction chart.

Framed 6-2-a Elevation

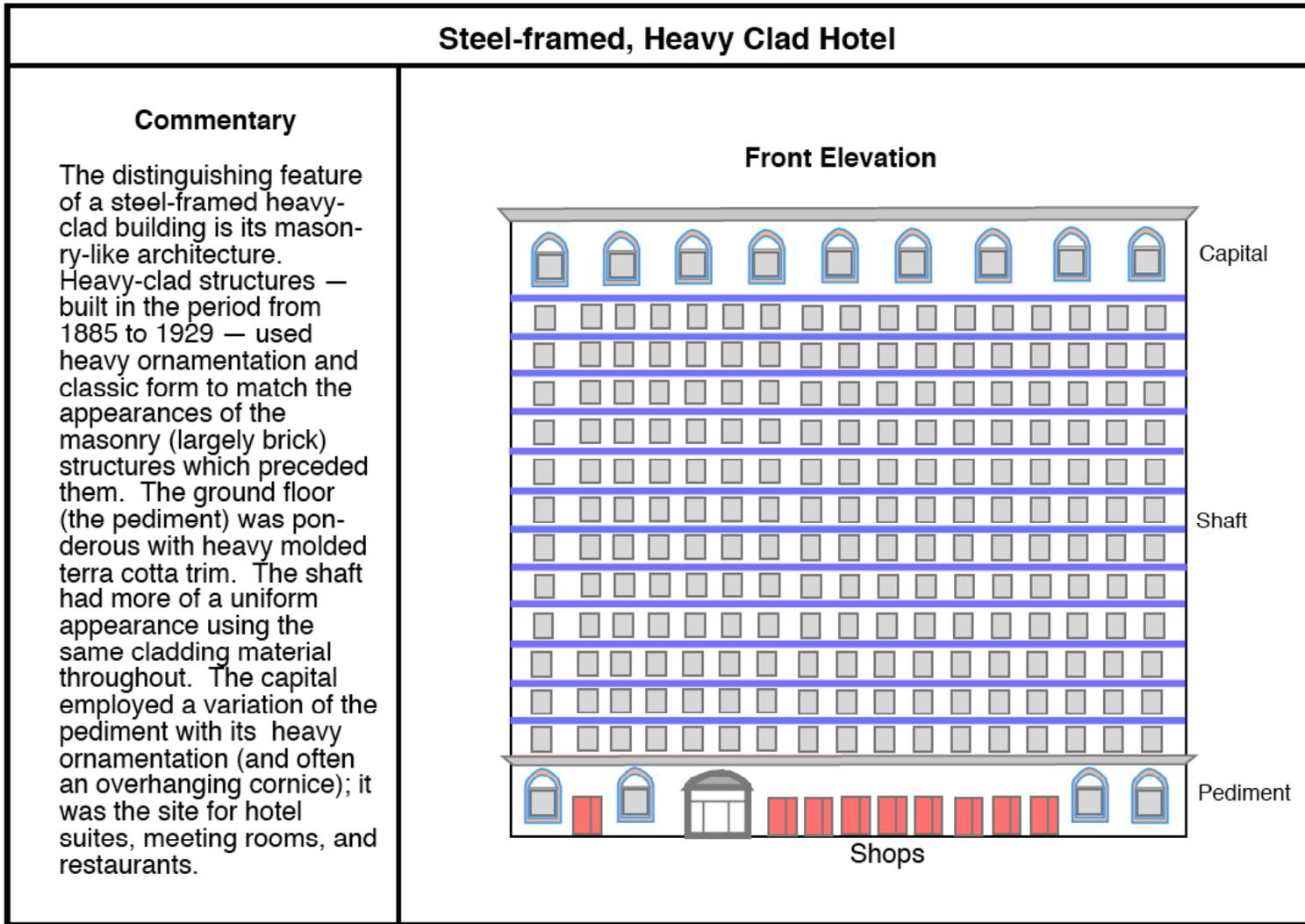


Figure 176. Framed 6-2-a elevation.

Framed 6-2-b Elevations

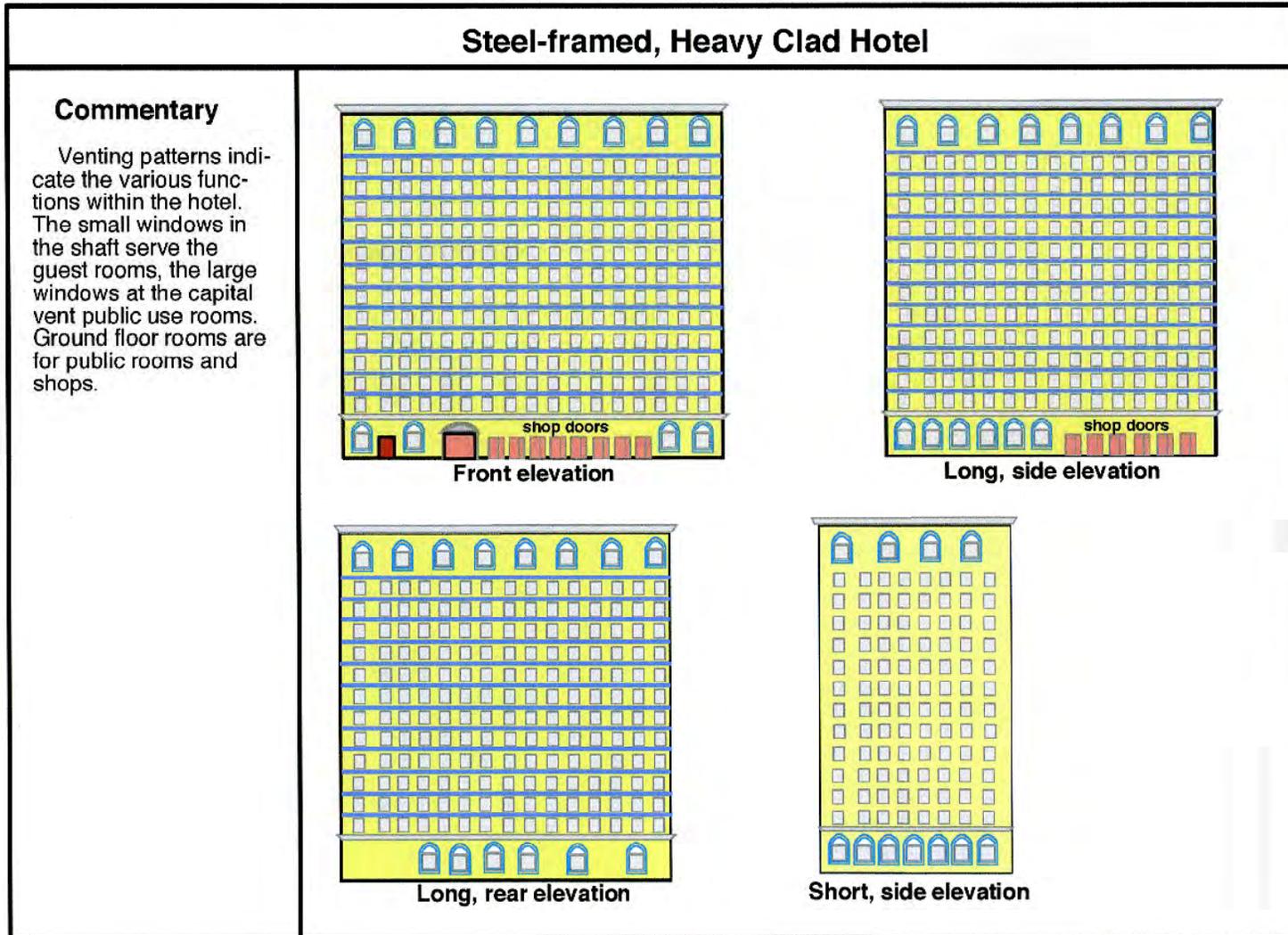


Figure 177. Framed 6-2-b elevations.

Framed 6-3-a Floor Plan

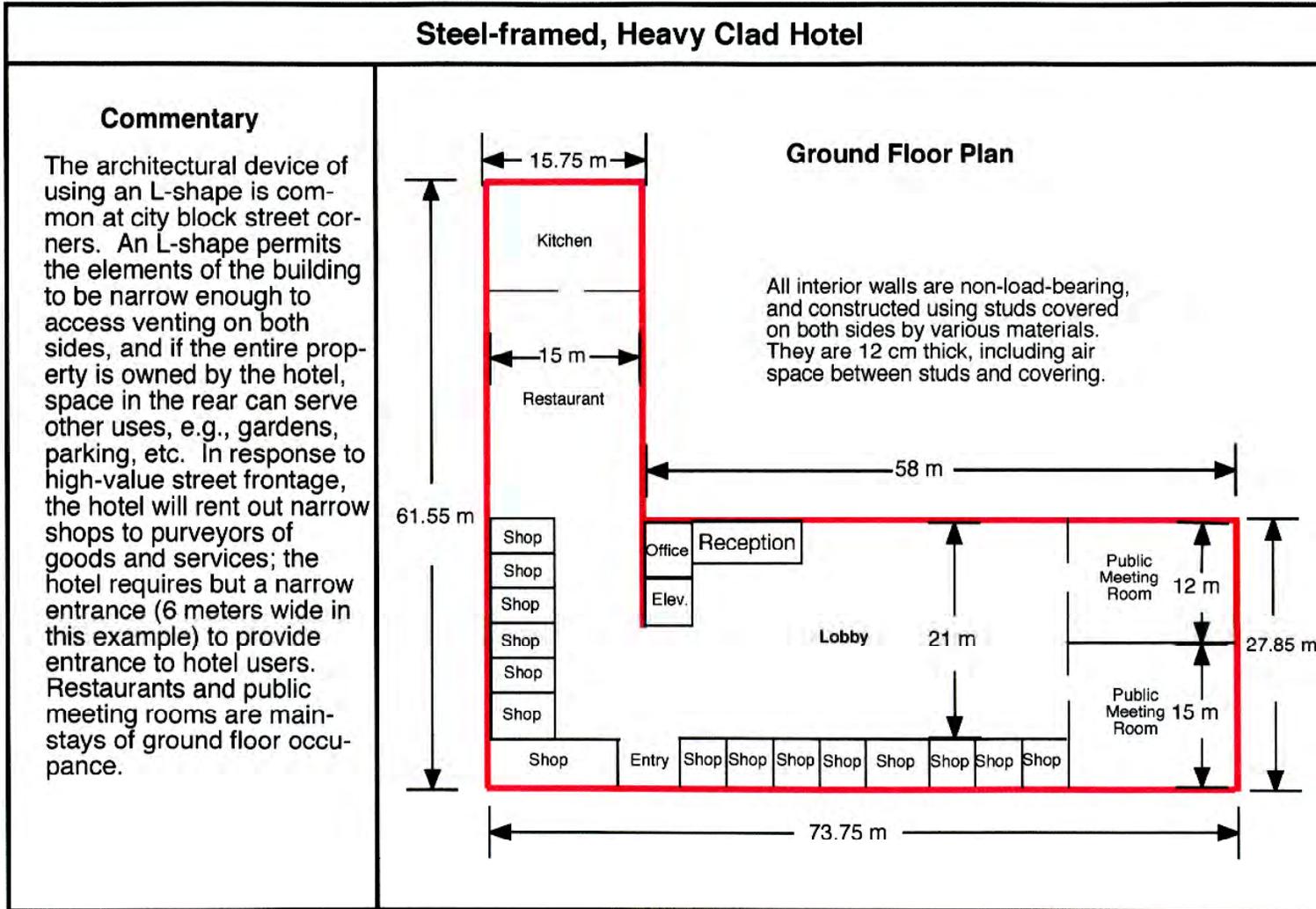


Figure 178. Framed 6-3-a floor plan.

Framed 6-3-b Floor Plan

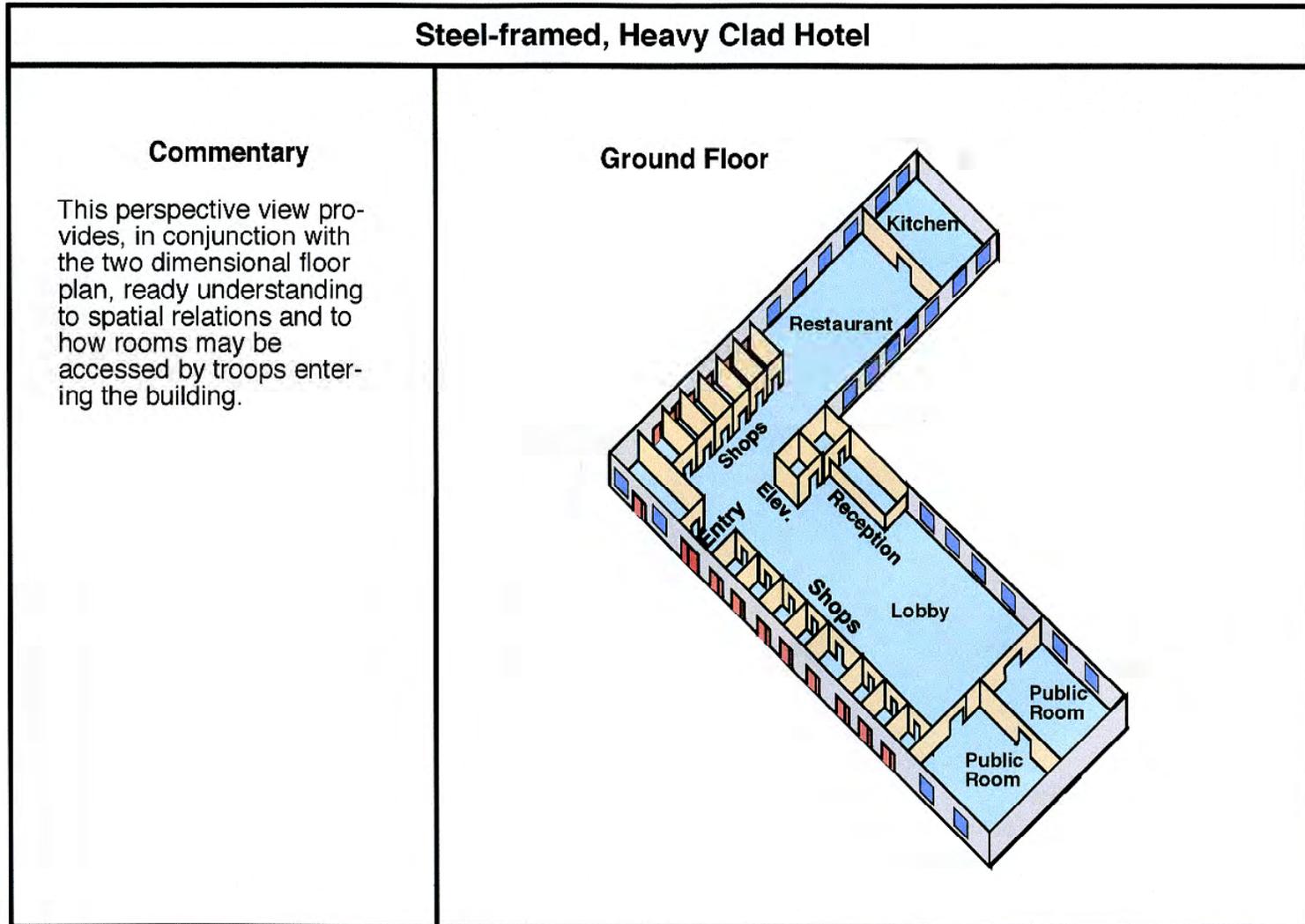
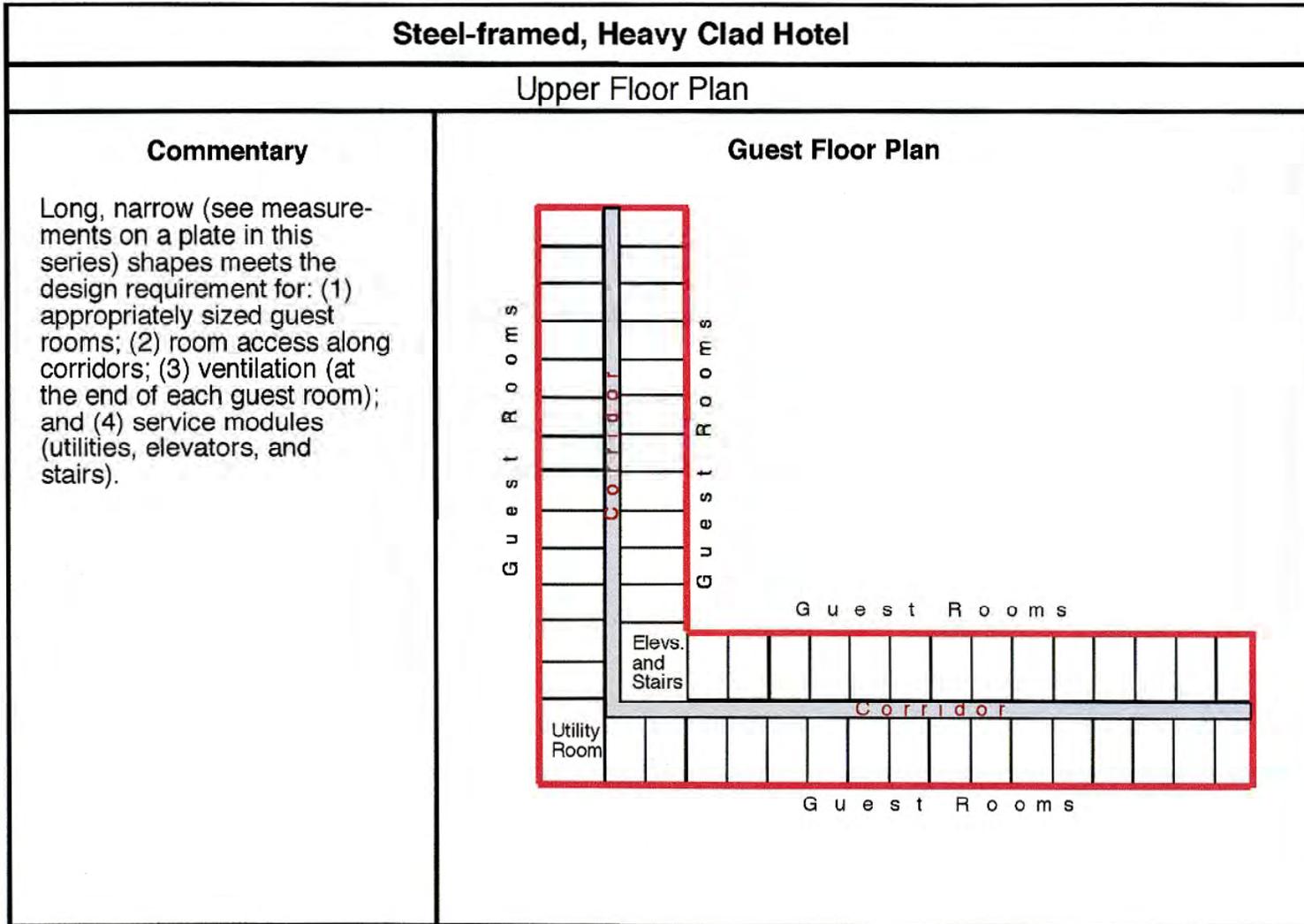


Figure 179. Framed 6-3-b floor plan.

Framed 6-3-c Floor Plan



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Figure 180. Framed 6-3-c floor plan.

Framed 6-3-d Floor Plan

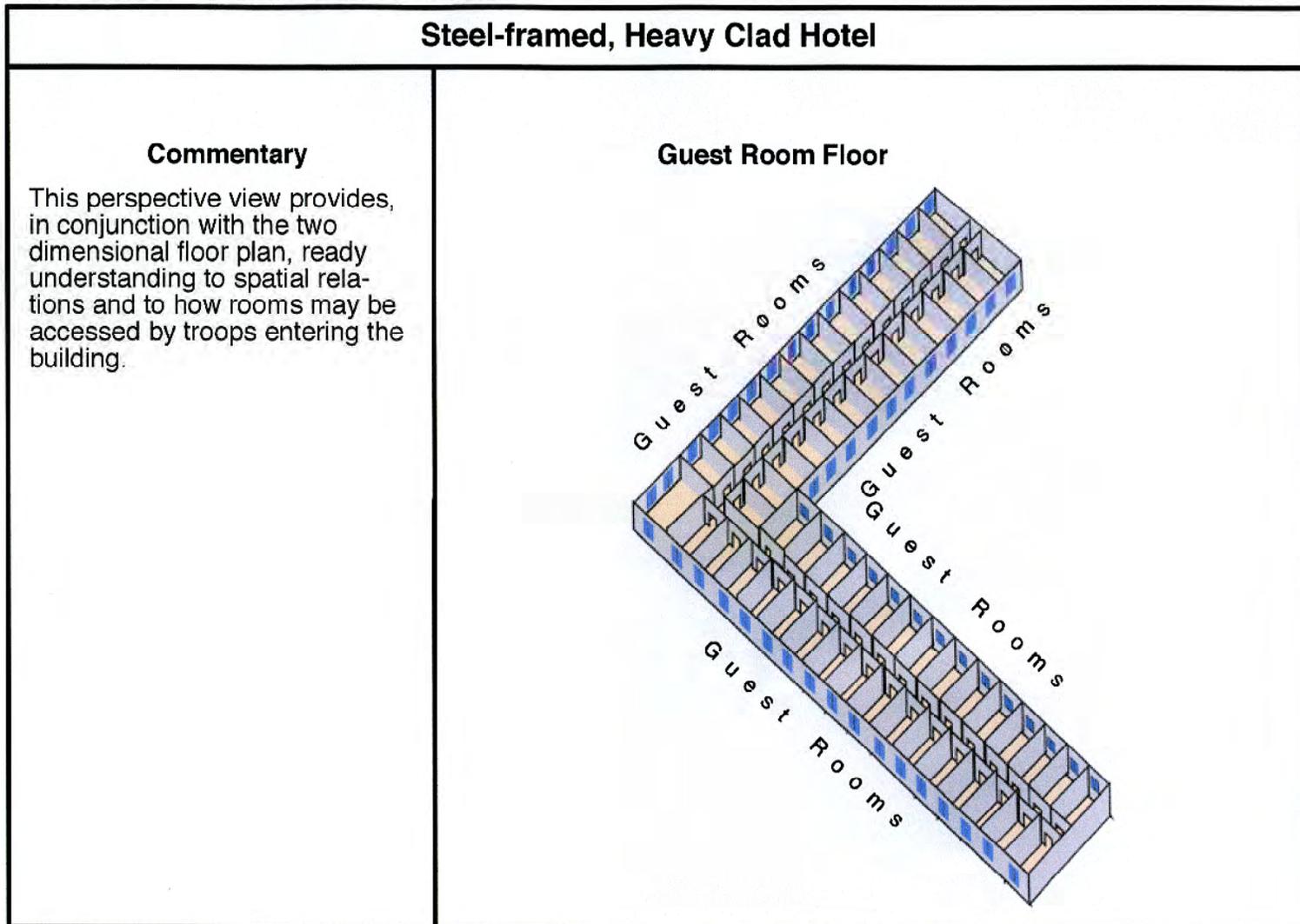


Figure 181. Framed 6-3-d floor plan.

Framed 6-4 Construction

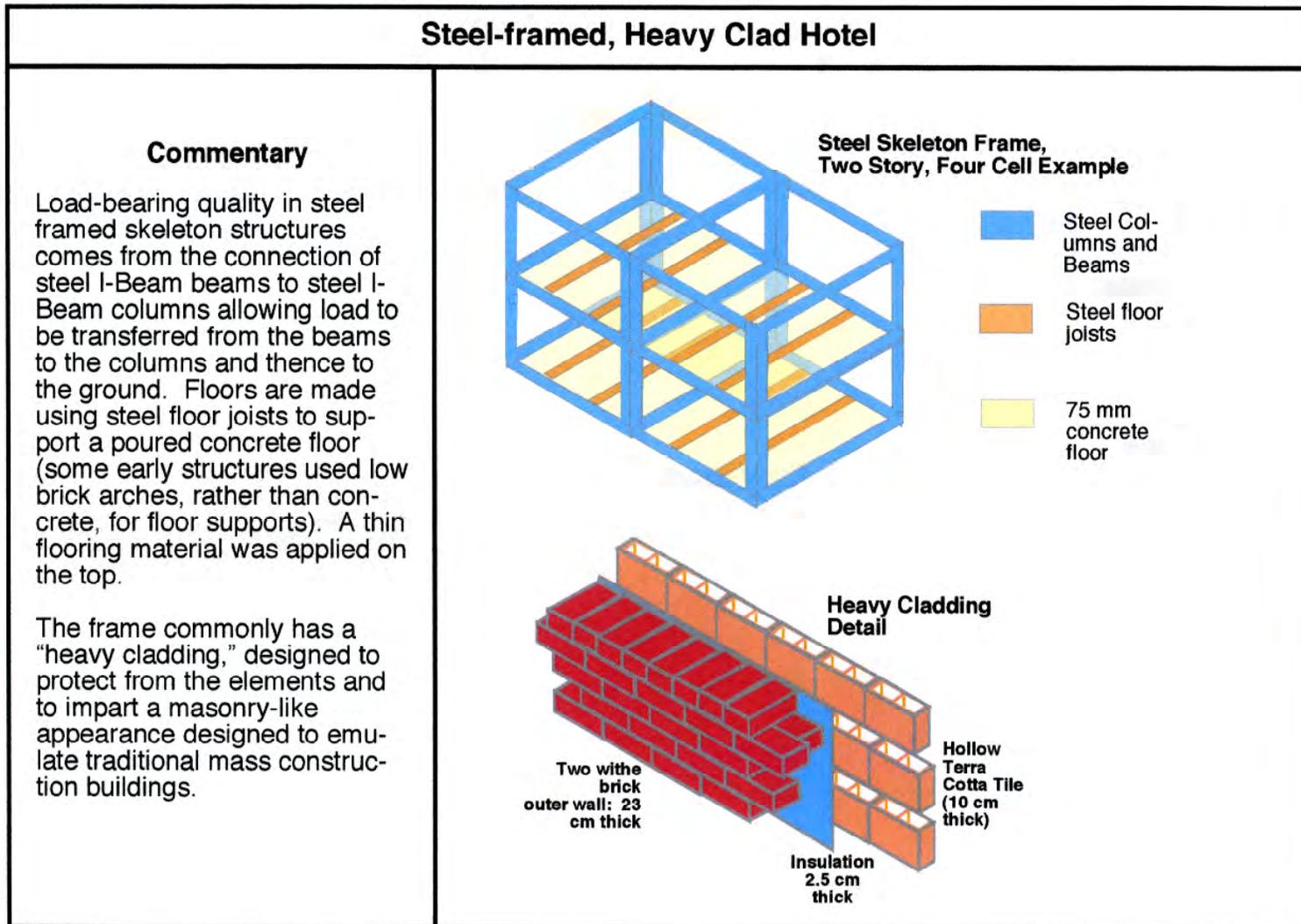


Figure 182. Framed 6-4 construction.

Framed 7-1 Place on Building Construction Chart

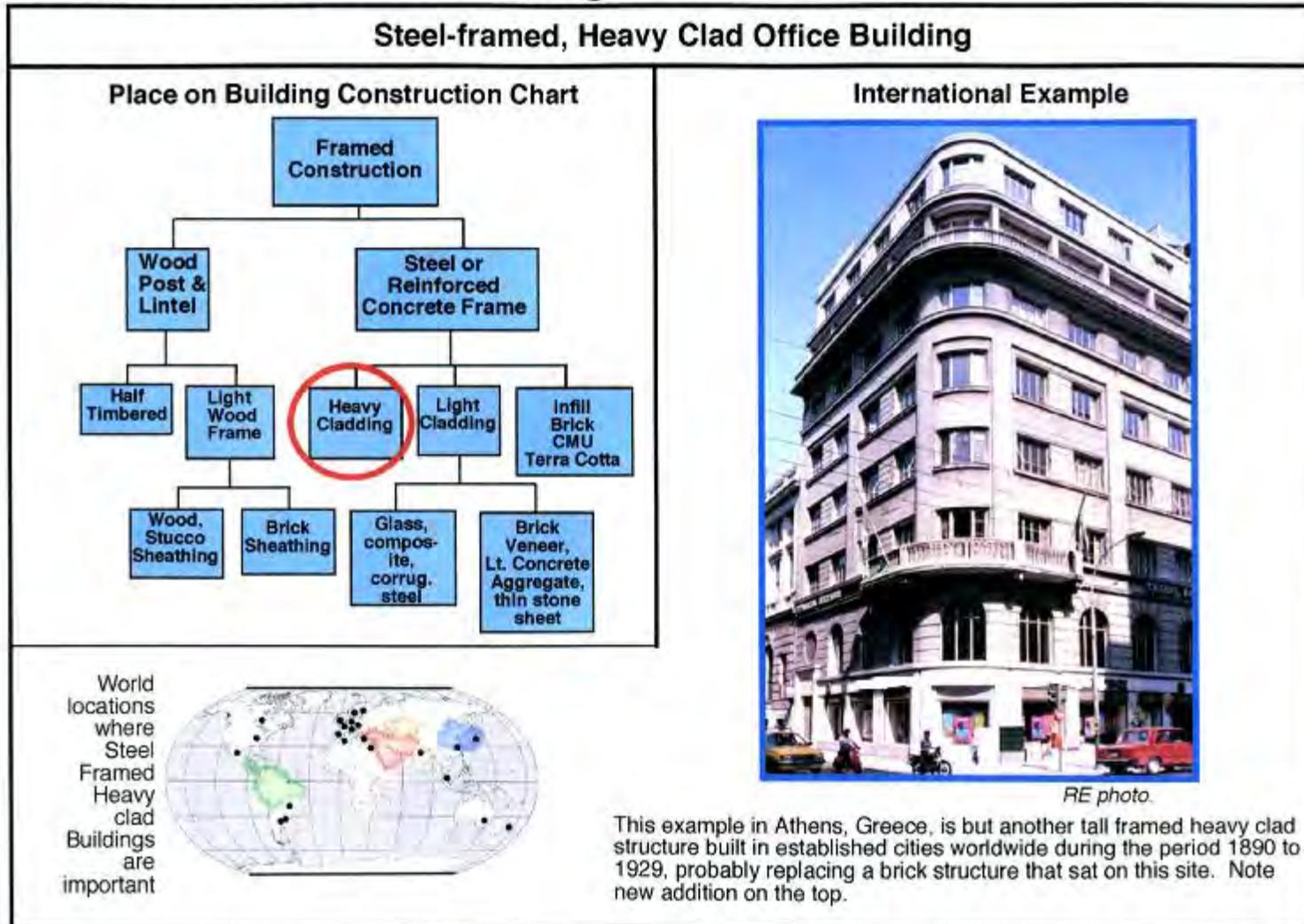


Figure 183. Framed 7-1 place on building construction chart.

Framed 7-2 Elevation

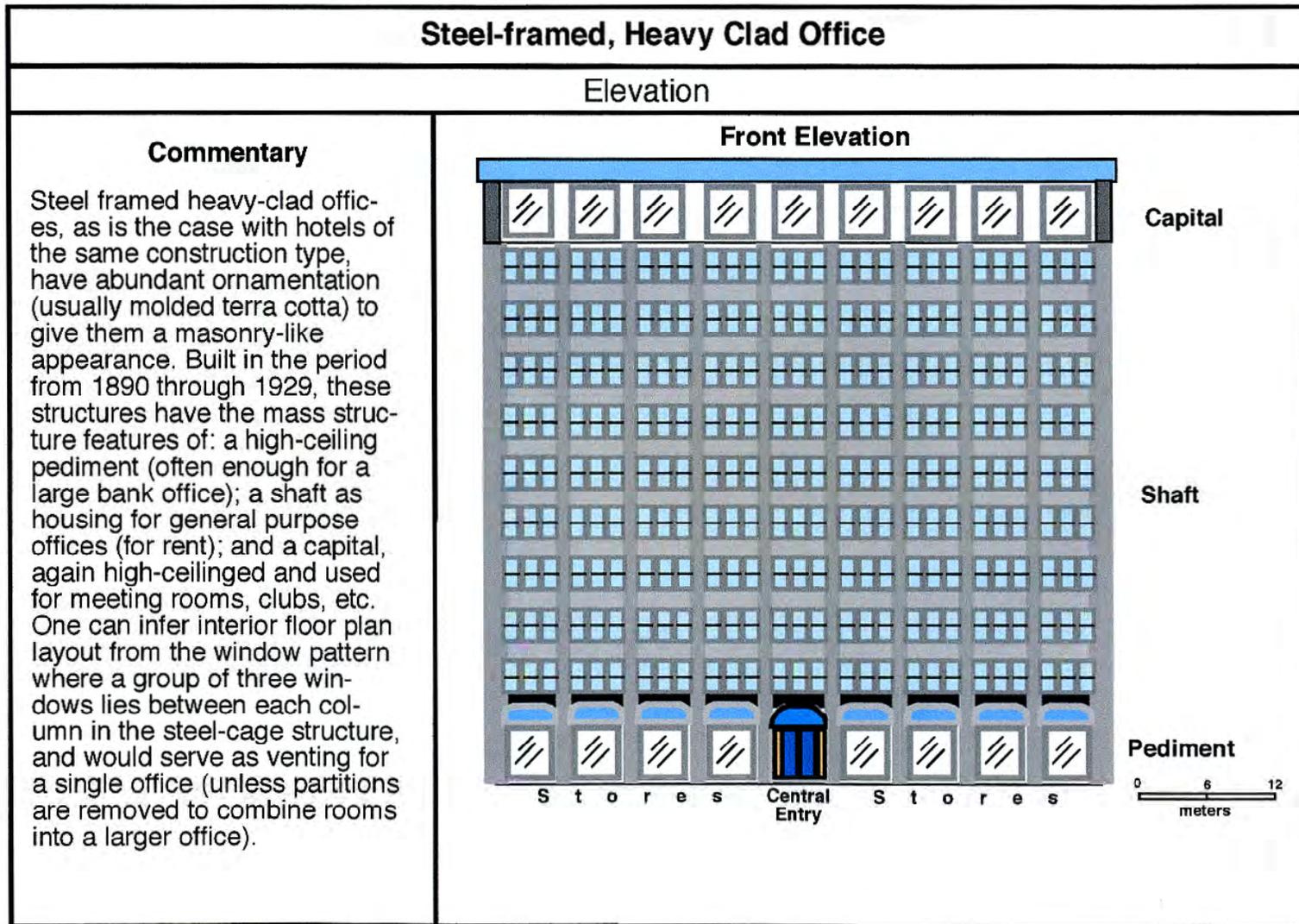
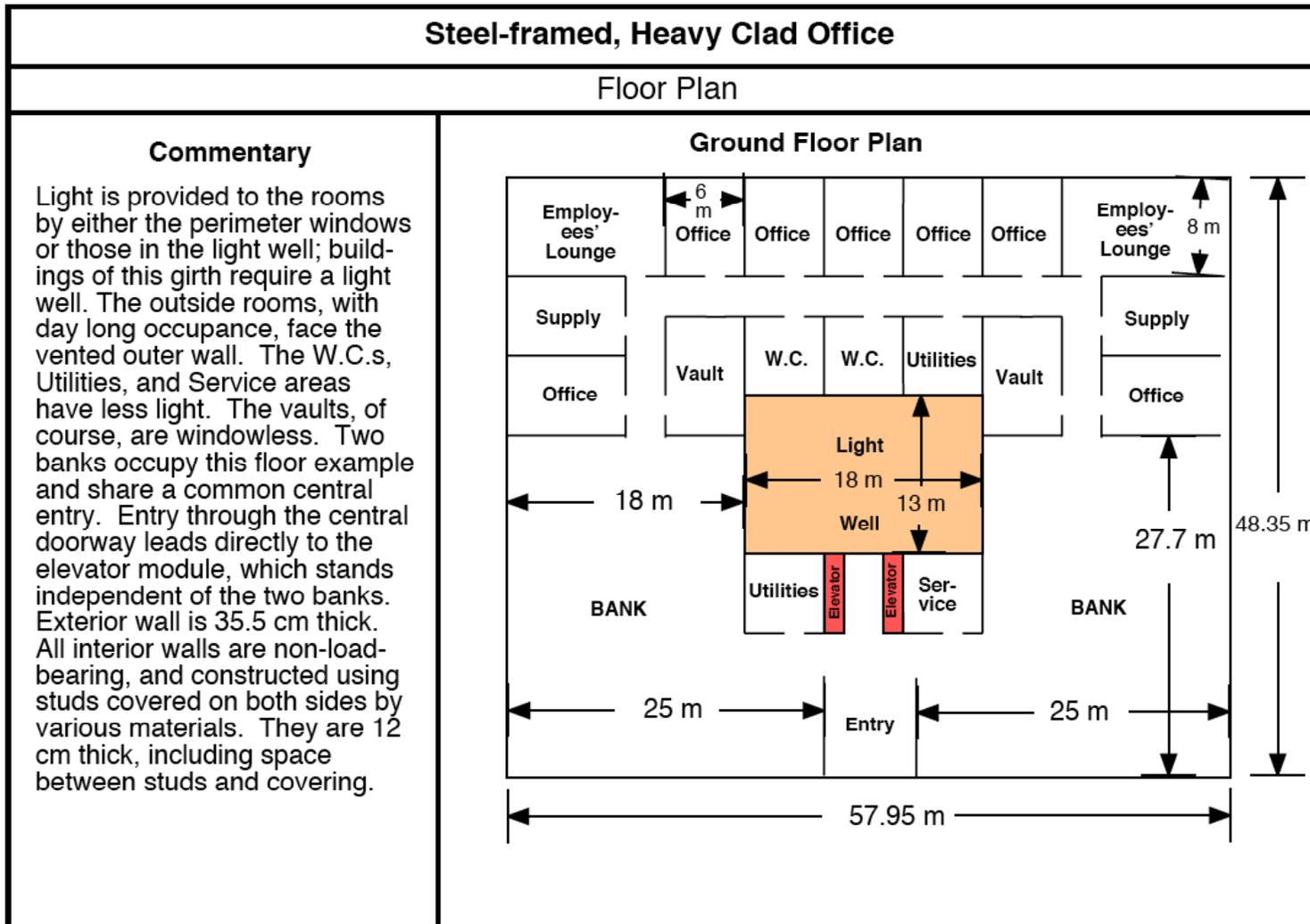


Figure 184. Framed 7-2 elevation.

Framed 7-3-a Floor Plan



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Figure 185. Framed 7-3-a floor plan.

Framed 7-3-b Floor Plan

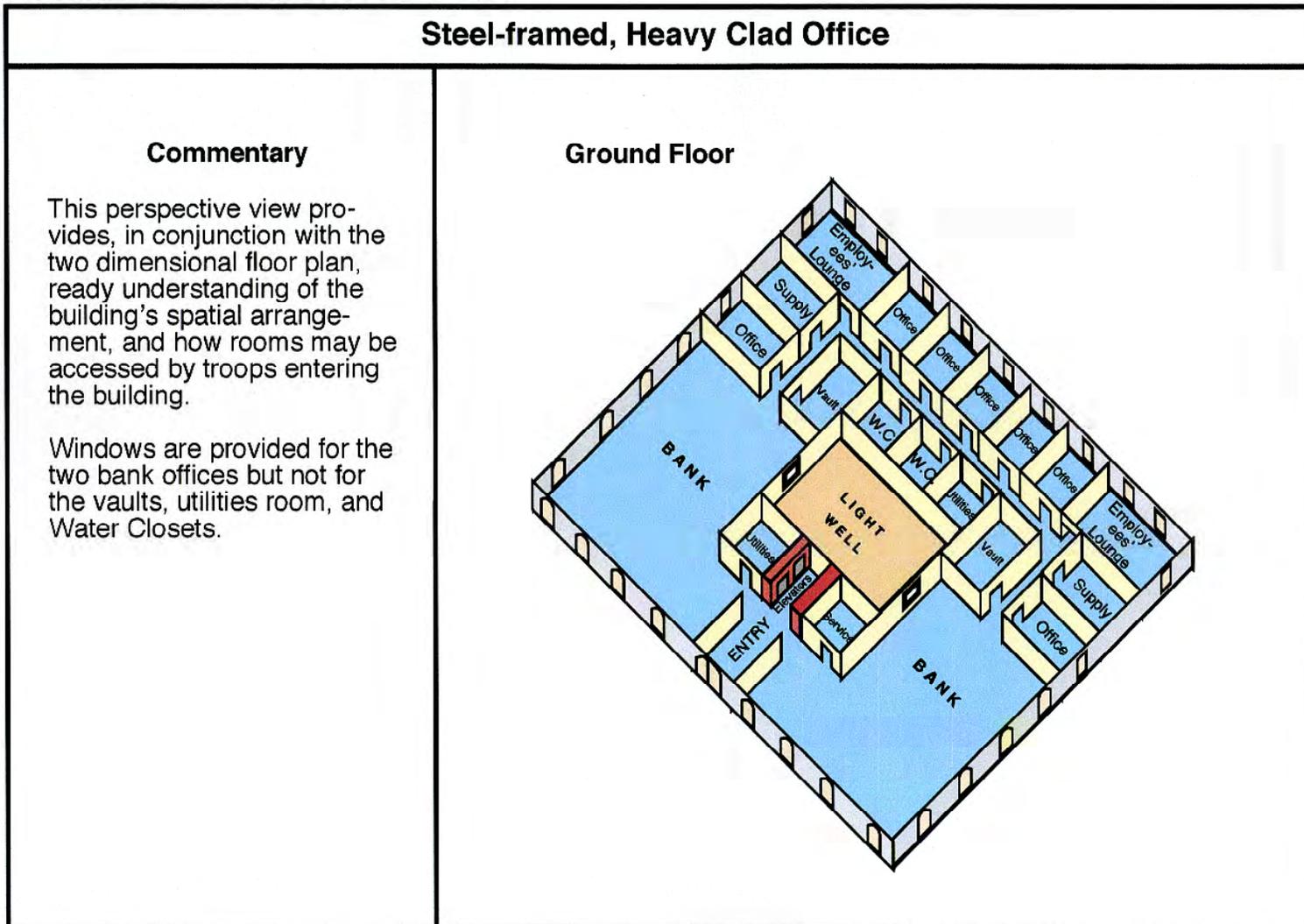


Figure 186. Framed 7-3-b floor plan.

Framed 7-3-c Floor Plan

Steel-framed, Heavy Clad Office

Commentary

As with the ground floor plan, offices have access to venting via the exterior wall of the building and the light well (albeit at lower light values). The corridor accesses the elevator and reaches all offices.

Upper Floor (offices)

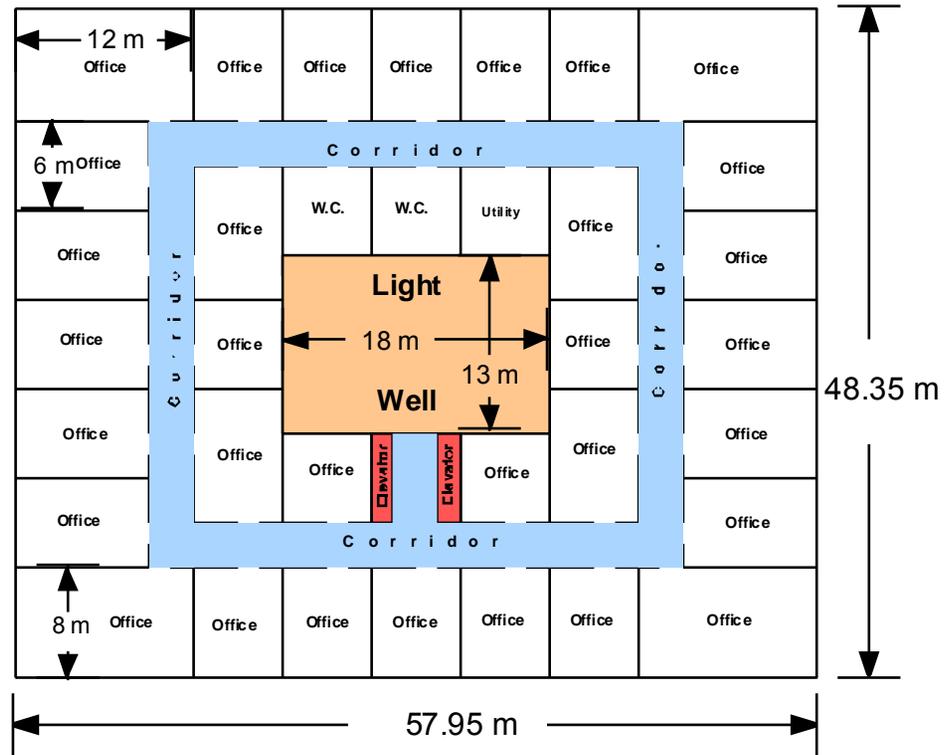


Figure 187. Framed 7-3-c floor plan.

Framed 7-3-d Floor Plan

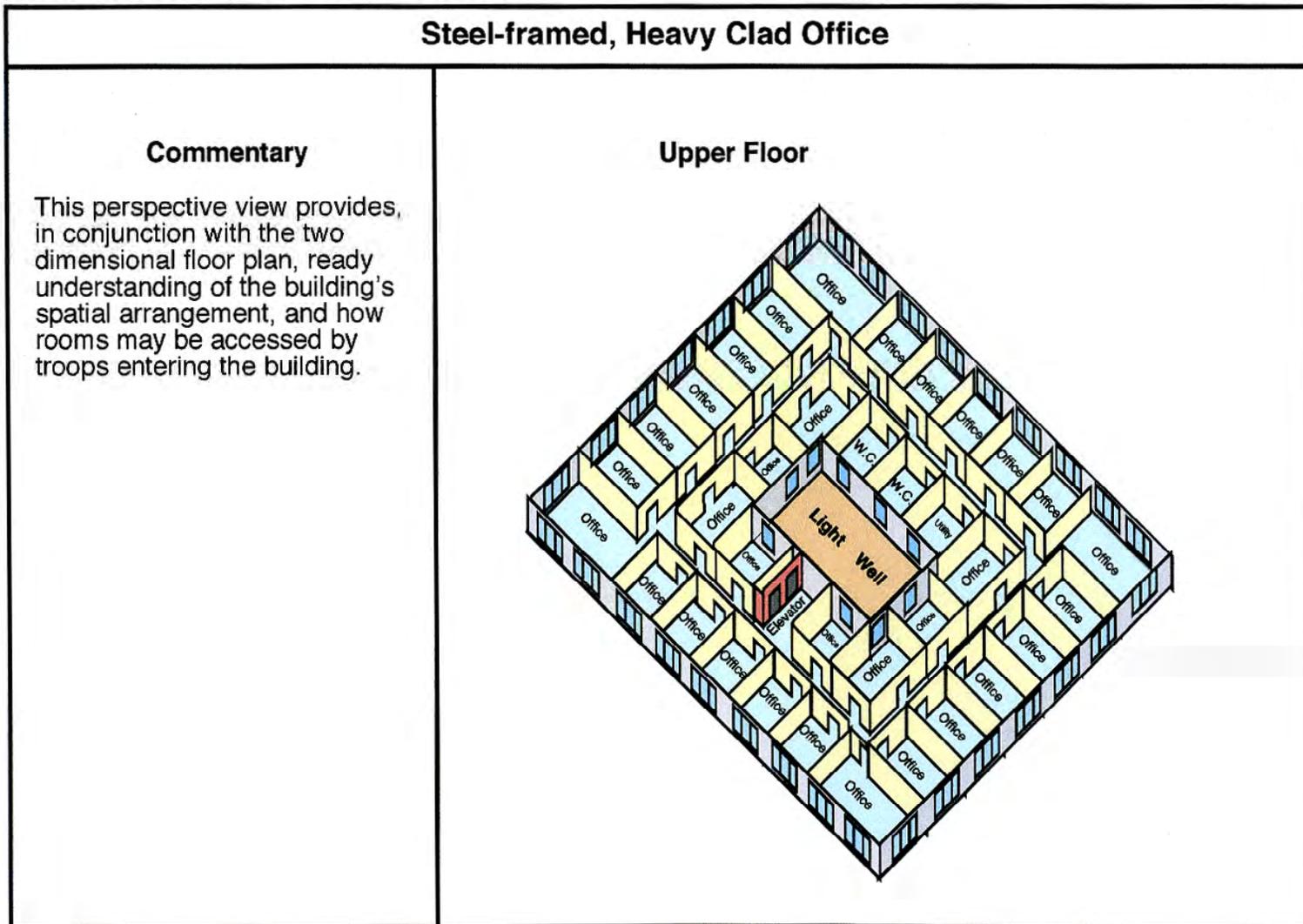


Figure 188. Framed 7-3-d floor plan.

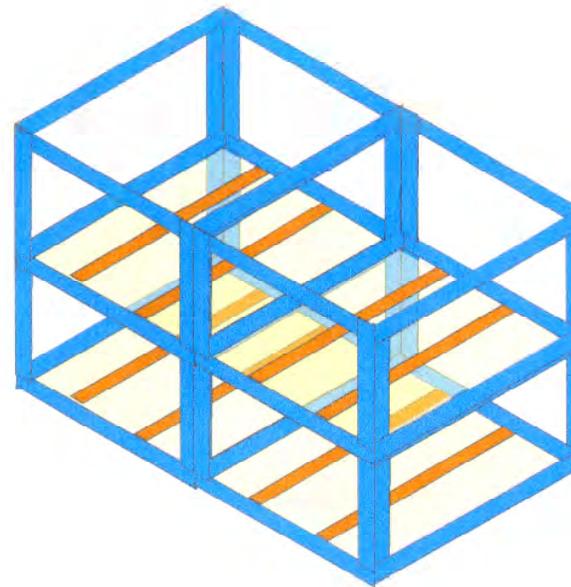
Framed 7-4-a Construction

Steel-framed, Heavy Clad Office Building

Commentary

Load-bearing quality in steel framed skeleton structures comes from the connection of steel I-Beam beams to steel I-Beam columns allowing load to be transferred from the beams to the columns and thence to the ground. Floors are made using steel floor joists to support a poured concrete floor (some early structures used low brick arches, rather than concrete, for floor supports). A thin flooring material was applied on the top.

Steel Skeleton Frame, Two Story, Four Cell Example



- Steel Columns and Beams
- Steel floor joists
- 75 mm concrete floor

Figure 189. Framed 7-4-a construction.

Framed 7-4-b Construction

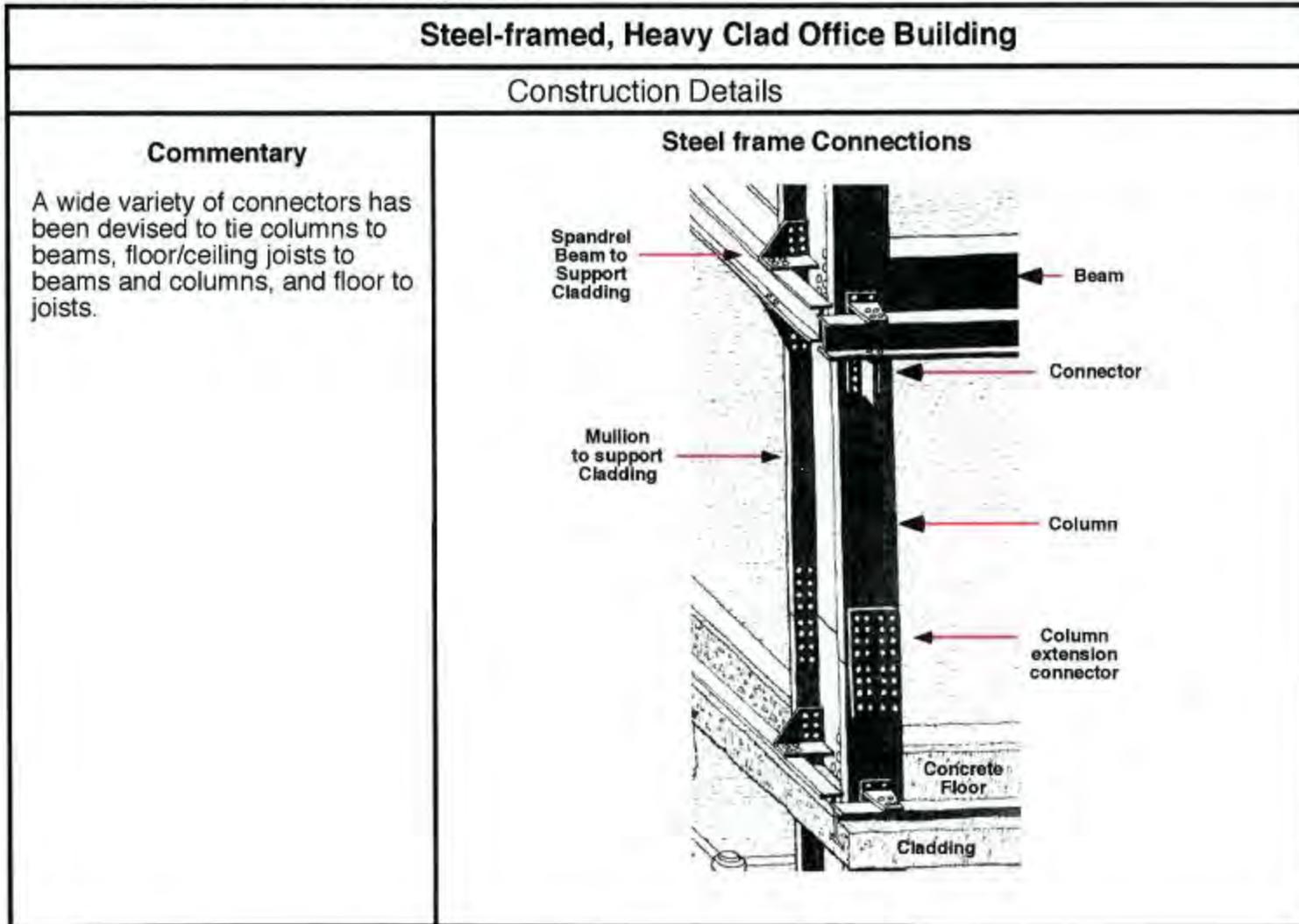


Figure 190. Framed 7-4-b construction.

Framed 7-4-c Construction

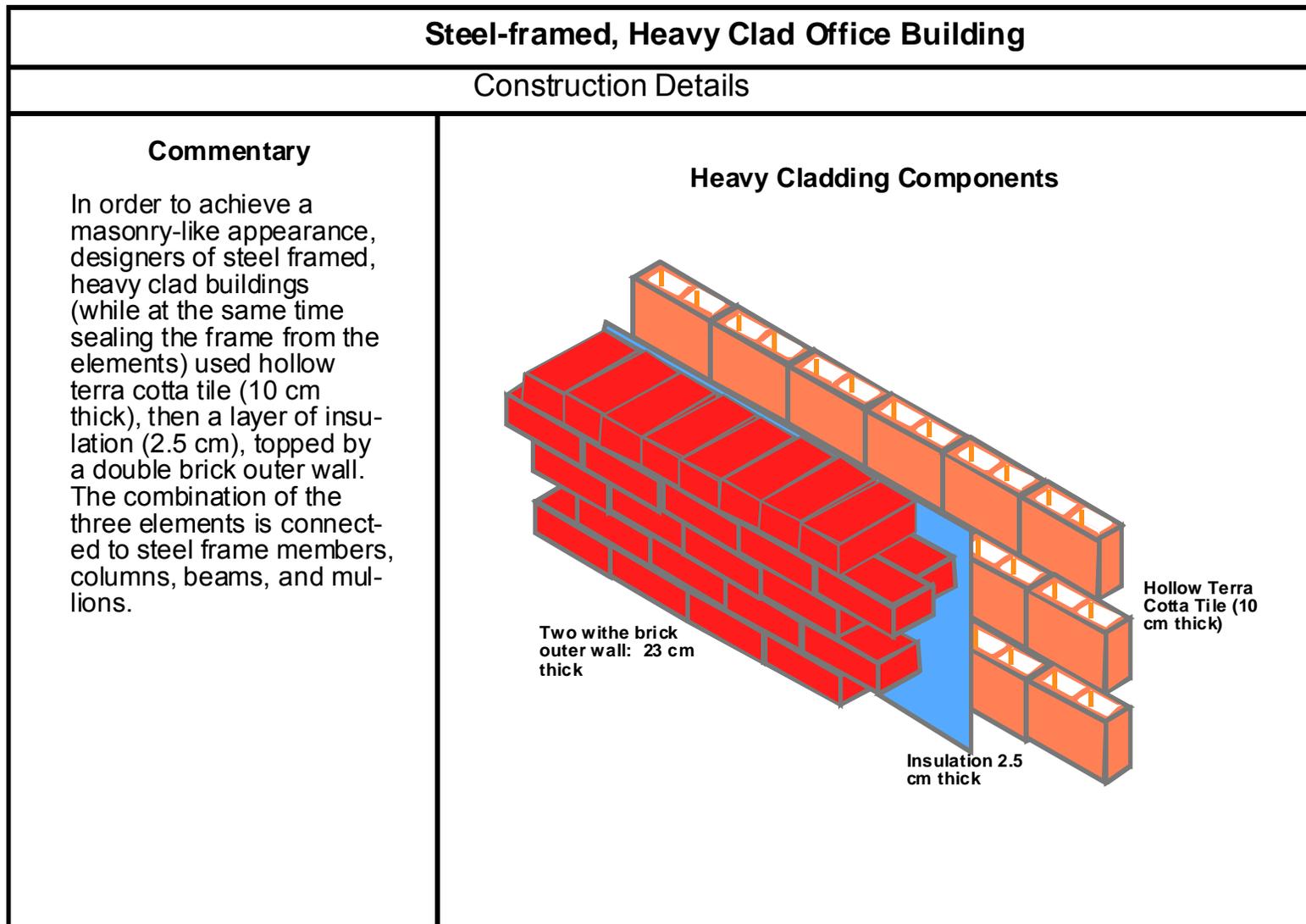


Figure 191. Framed 7-4-c construction.

Framed 8-1 Place on Building Construction Chart

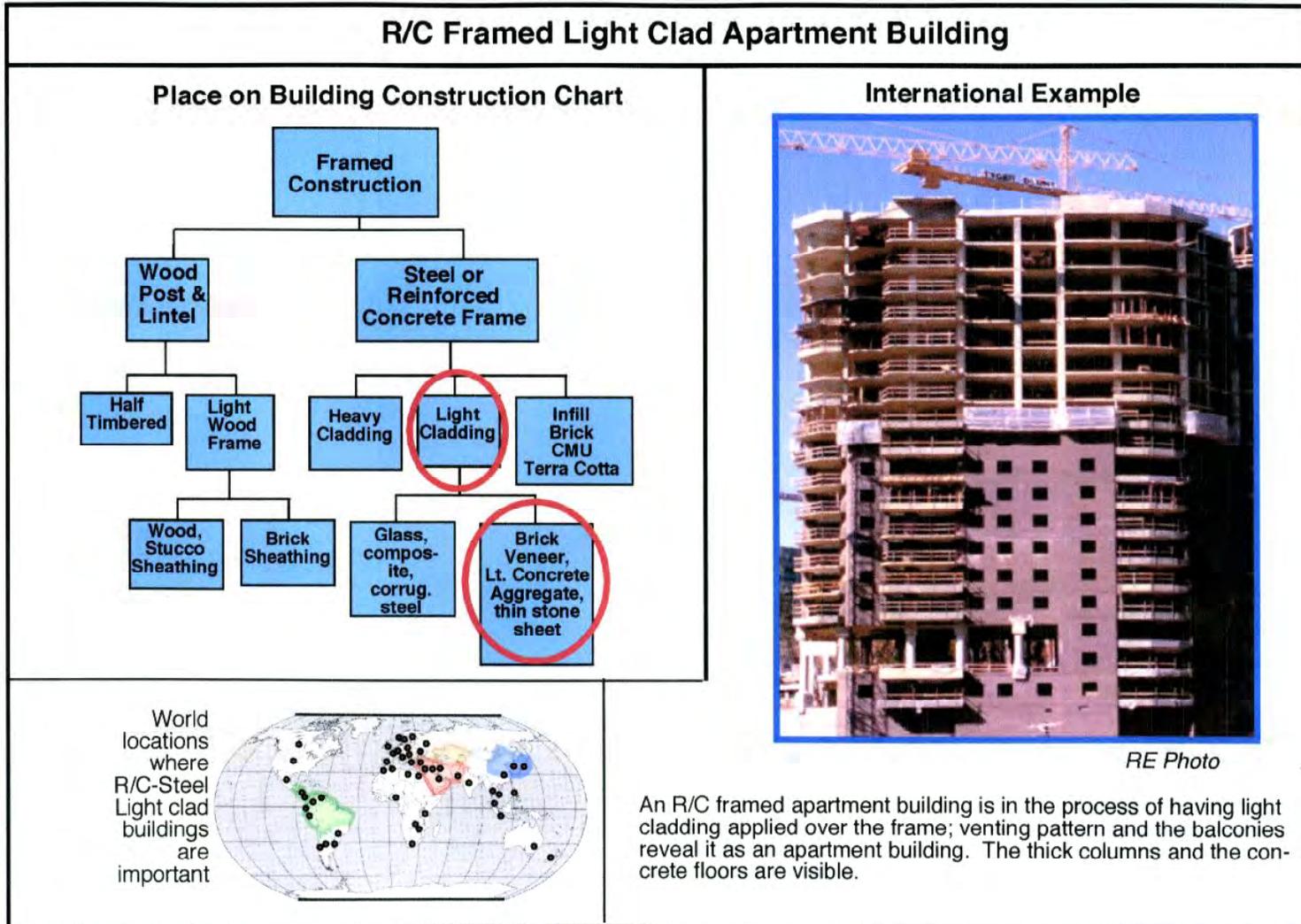
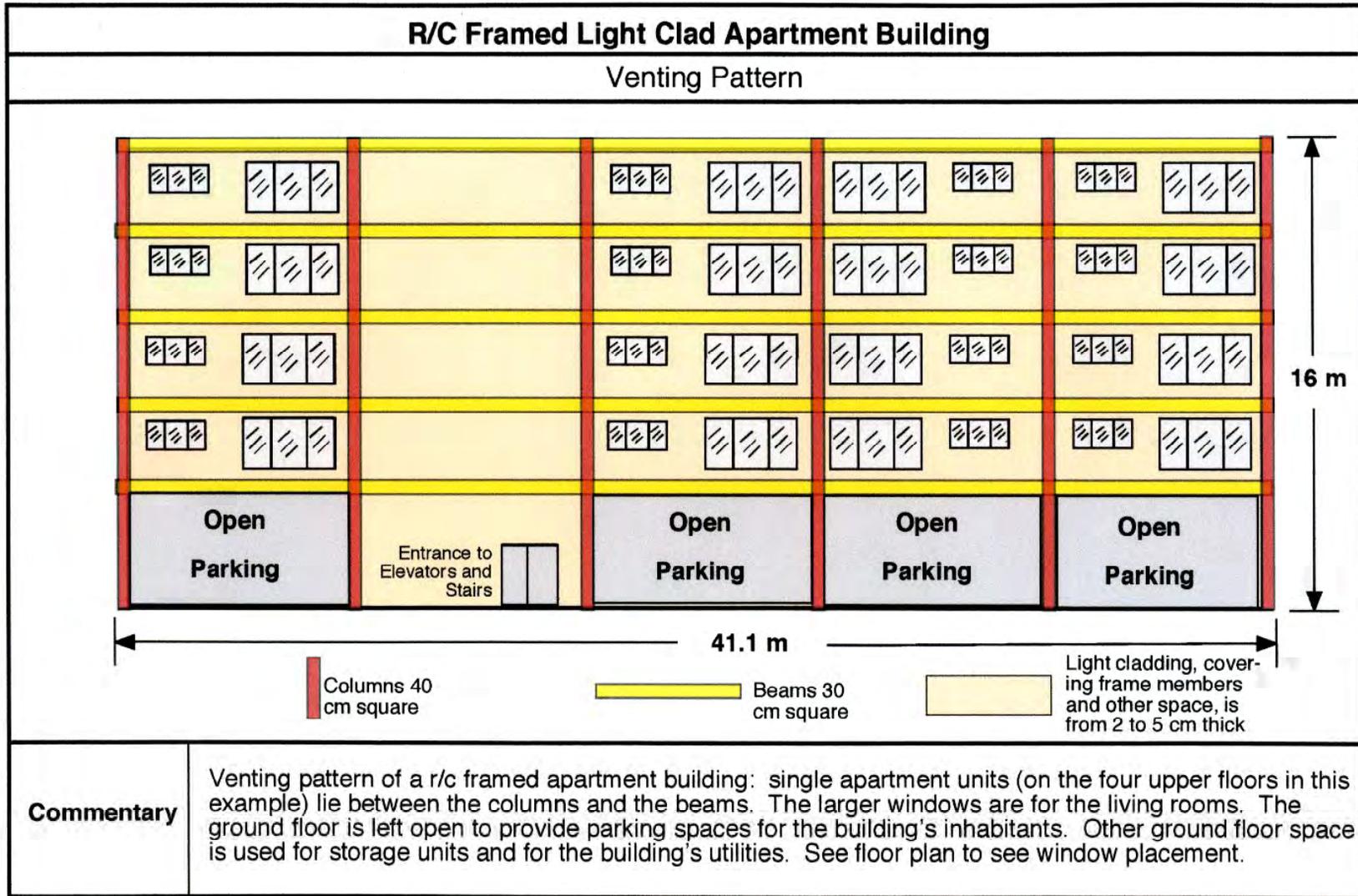


Figure 192. Framed 8-1 place on building construction chart.

Framed 8-2 Elevation



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Figure 193. Framed 8-2 elevation.

Framed 8-3-a Floor Plan

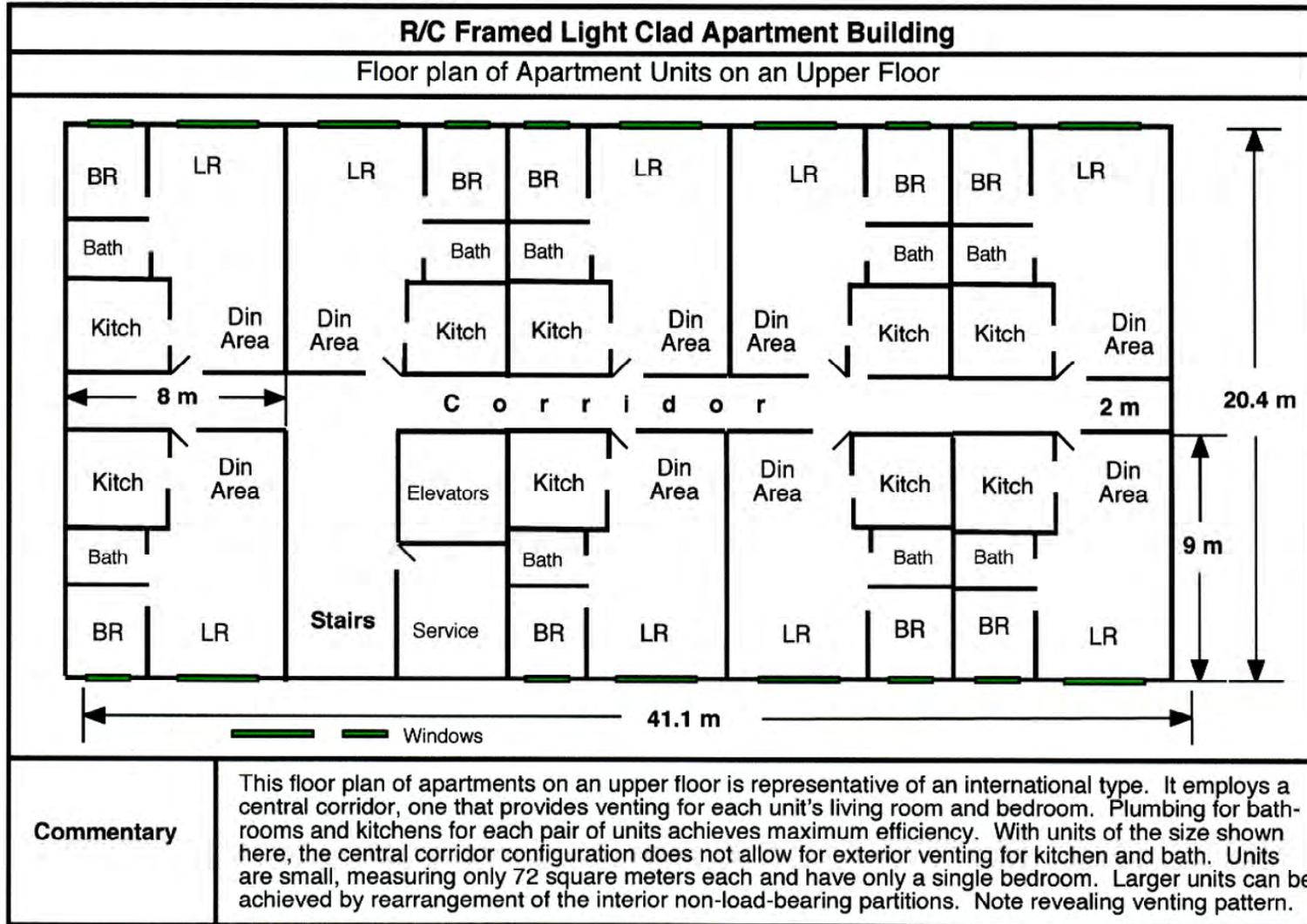


Figure 194. Framed 8-3-a floor plan.

Framed 8-4 Construction

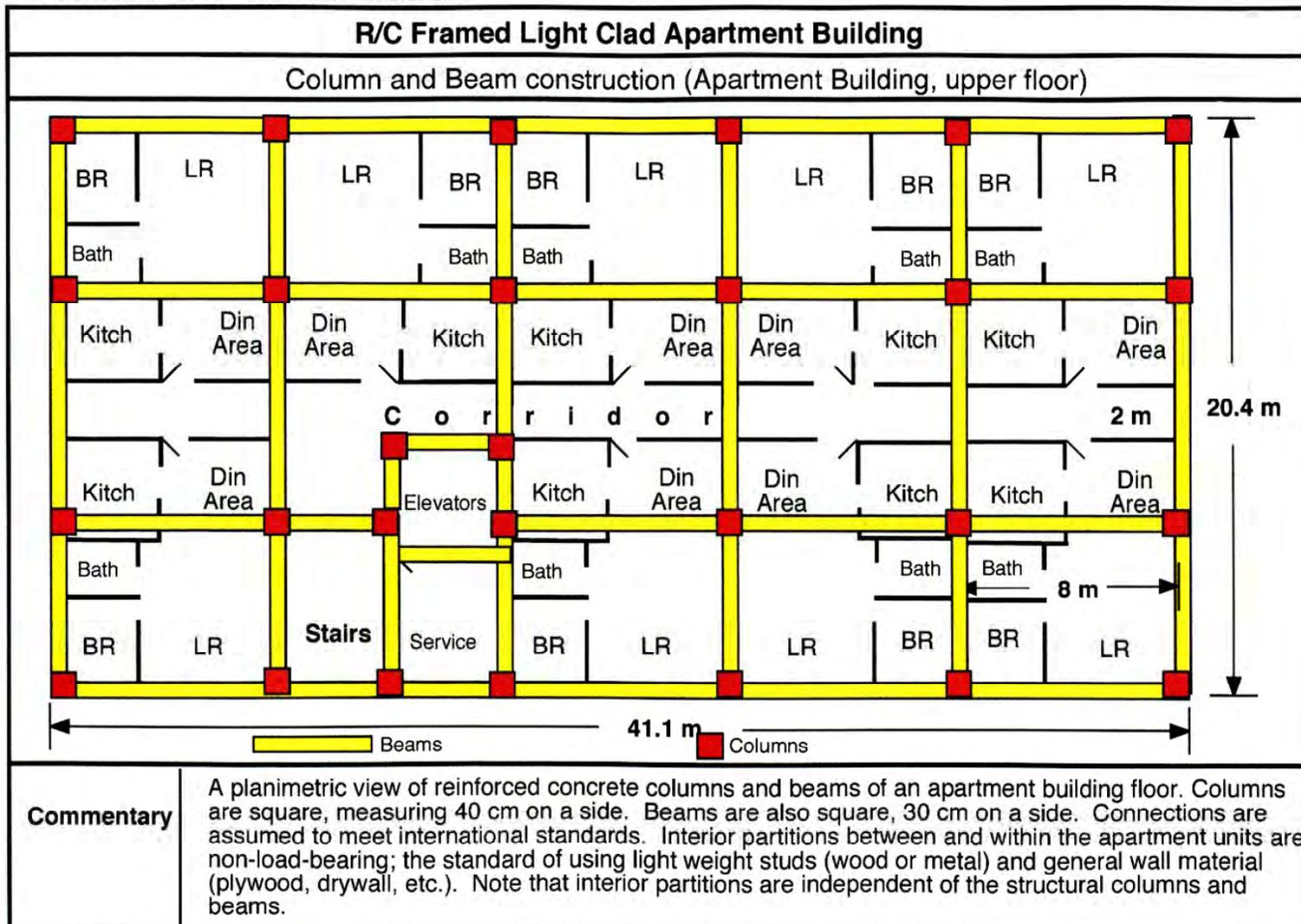


Figure 195. Framed 8-4 construction.

Framed 9-1 Place on Building Construction Chart

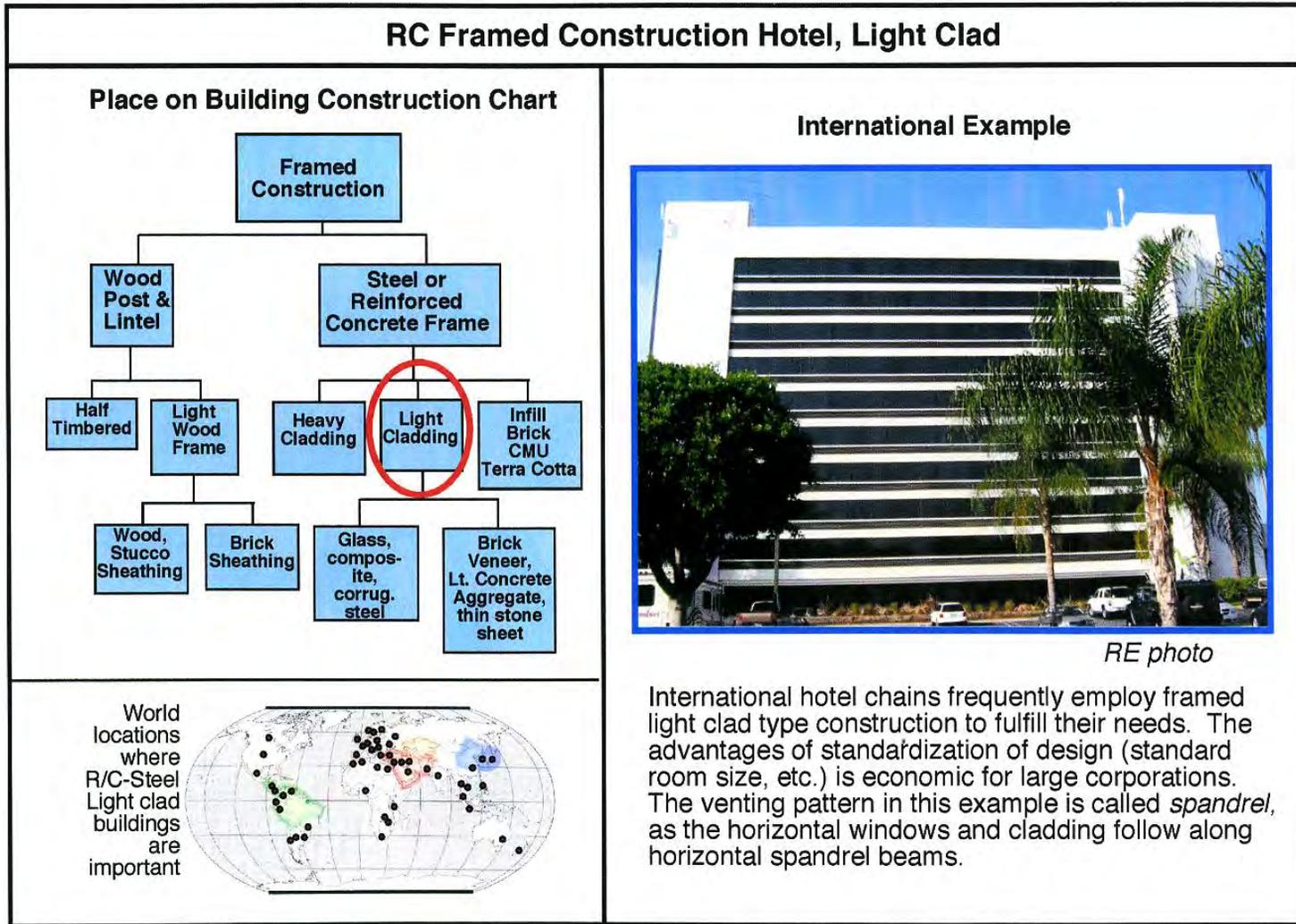
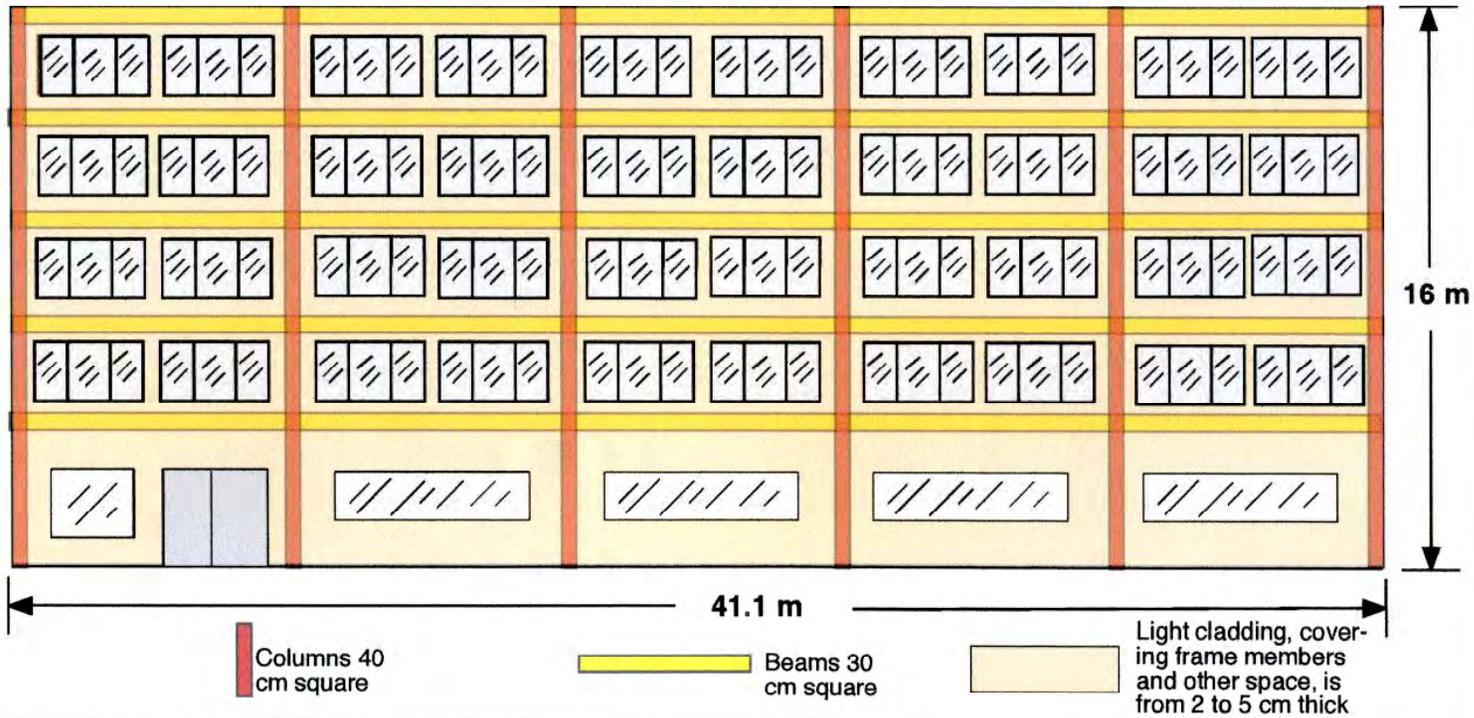


Figure 196. Framed 9-1 place on building construction chart.

Framed 9-2 Elevation

RC Framed Construction Hotel, Light Clad



Commentary

Venting pattern of a r/c framed hotel: two 4m guest rooms (on the four upper floors in this example) lie between sets of two columns. Thus, windows are large forming almost all of the end wall of each guest room (providing its only natural lighting, see floor plan). The ground floor differs. It is taller (has higher ceilings) and provides space for public functions, i.e., lobby, restaurant, business office, and public meeting rooms. All non vented wall surface is a light cladding covering the frame and spaces between.

Figure 197. Framed 9-2 elevation.

Framed 9-3-a Floor Plan

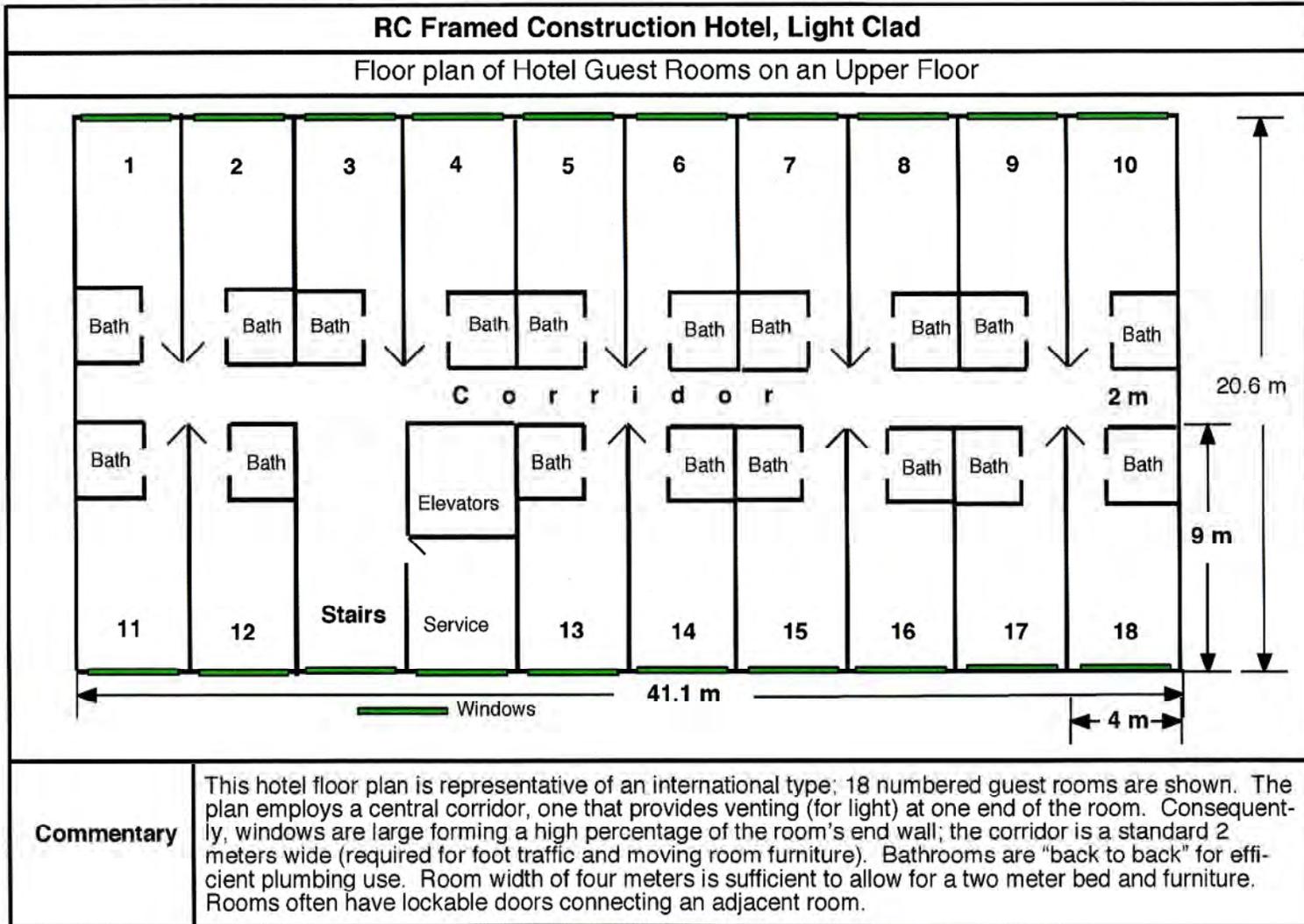


Figure 198. Framed 9-3-a floor plan.

Framed 9-3-b Floor Plan

RC Framed Construction Hotel, Light Clad

Commentary

Common dimensions are used here: corridors are 2 meters wide; rooms (including bath) are 4 x 8 meters; baths are 2 x 2 meters. Efficient use of plumbing is achieved by back-to-back baths. Beams span 8 meters between columns. Partitions use 12 cm stud walls (in many older, steel-framed heavy clad hotels these walls use lath and plaster).

Guest Rooms Detail

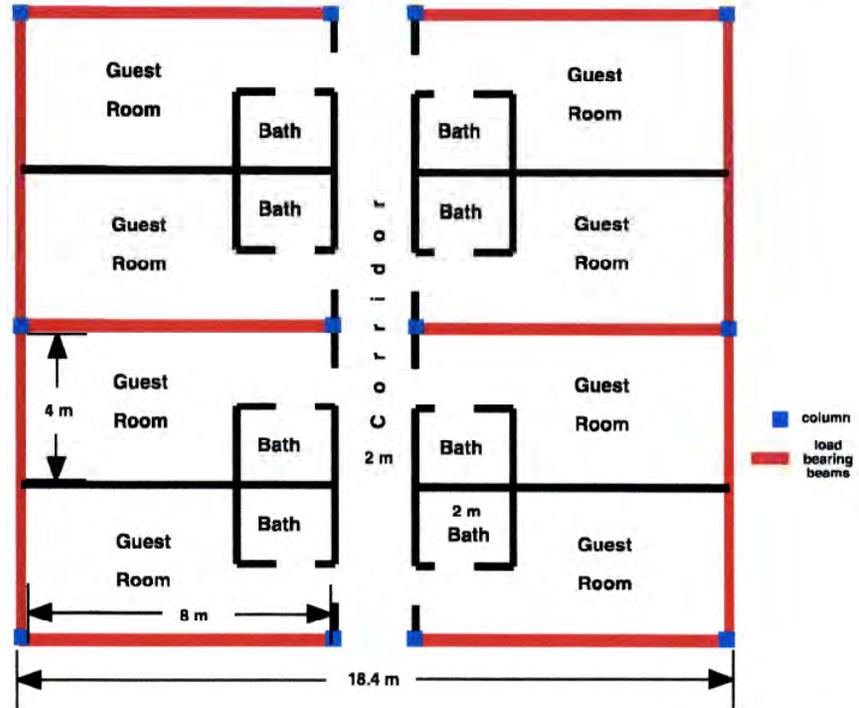


Figure 199. Framed 9-3-b floor plan.

Framed 9-3-c Floor Plan

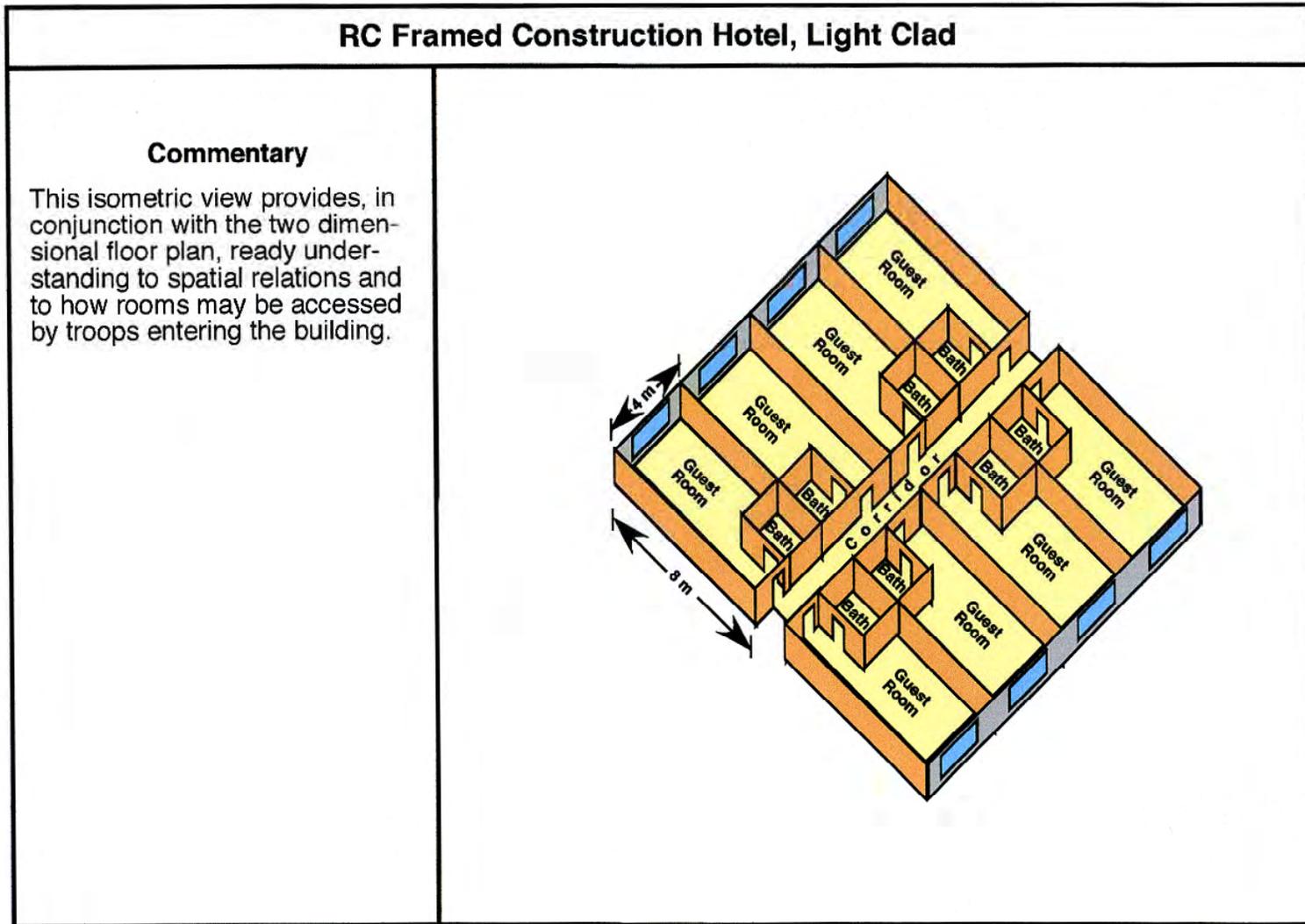


Figure 200. Framed 9-3-c floor plan.

Framed 9-4-a Construction

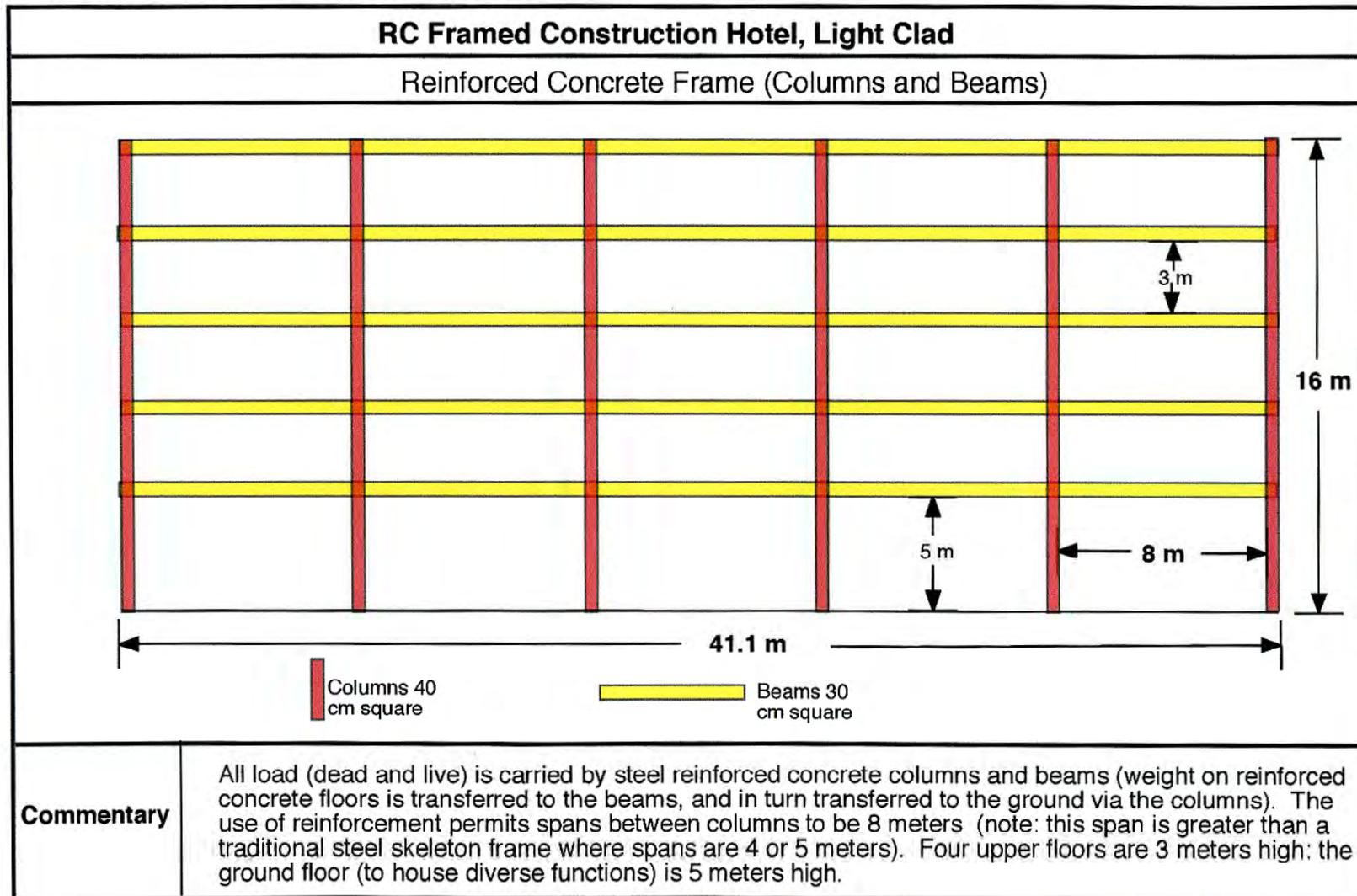


Figure 201. Framed 9-4-a construction.

Framed 9-4-b Construction

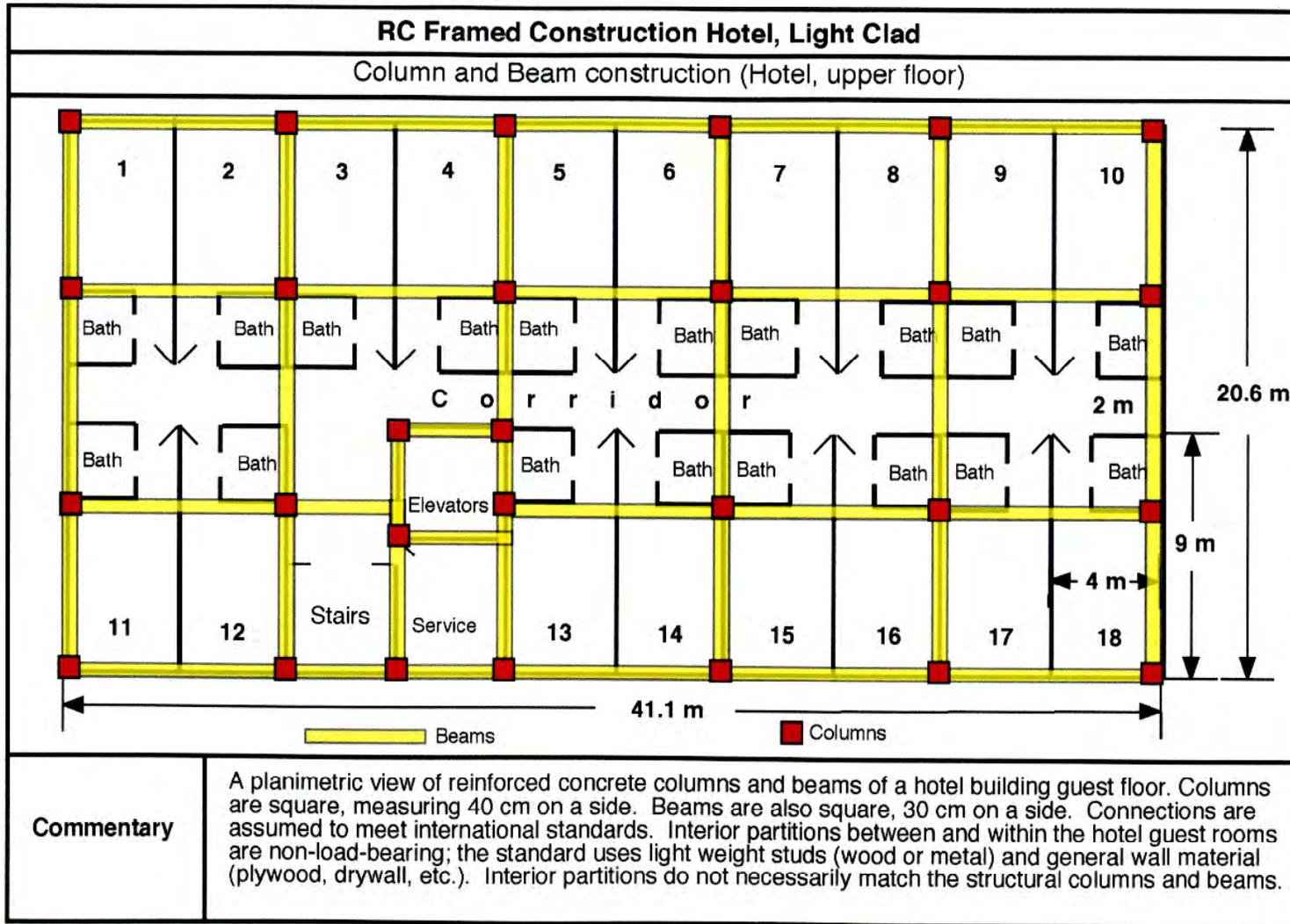


Figure 202. Framed 9-4-b construction.

Framed 9-4-c Construction

RC Framed Construction Hotel, Light Clad	
Construction Method and Dimensions	
<p style="text-align: center;">Commentary</p> <p>Many fundamental characteristics of re-enforced concrete framed buildings are seen in the example, from Tel Aviv.</p> <p>The intended function of the building will be that of a hotel, judging from the venting pattern. The cladding is light, being some highly reflective material; it is affixed to light weight mullions (vertical members). The columns are made of reinforced concrete, spaced some four meters apart. Column shapes vary from square to rectangular, ranging from 30 x 30 cm to 30 by 50 cm. The floor/ceilings are also of concrete (commonly some 10 to 15 cm thick). The lower three stories — serving functions such as public gathering, lobby, and restaurants — have what is probably foamed concrete cladding, to give the impression of stability and strength.</p> <p>Strengths:</p> <p>R/C columns: 356 kg/cm²</p> <p>R/C floors: 356 kg/cm²</p>	<p style="text-align: center;">Concrete Framed building under construction in Tel Aviv</p>  <p style="text-align: center;"><i>RE Photo</i></p>

Figure 203. Framed 9-4-c construction.

Framed 10-1 Place on Building Construction Chart

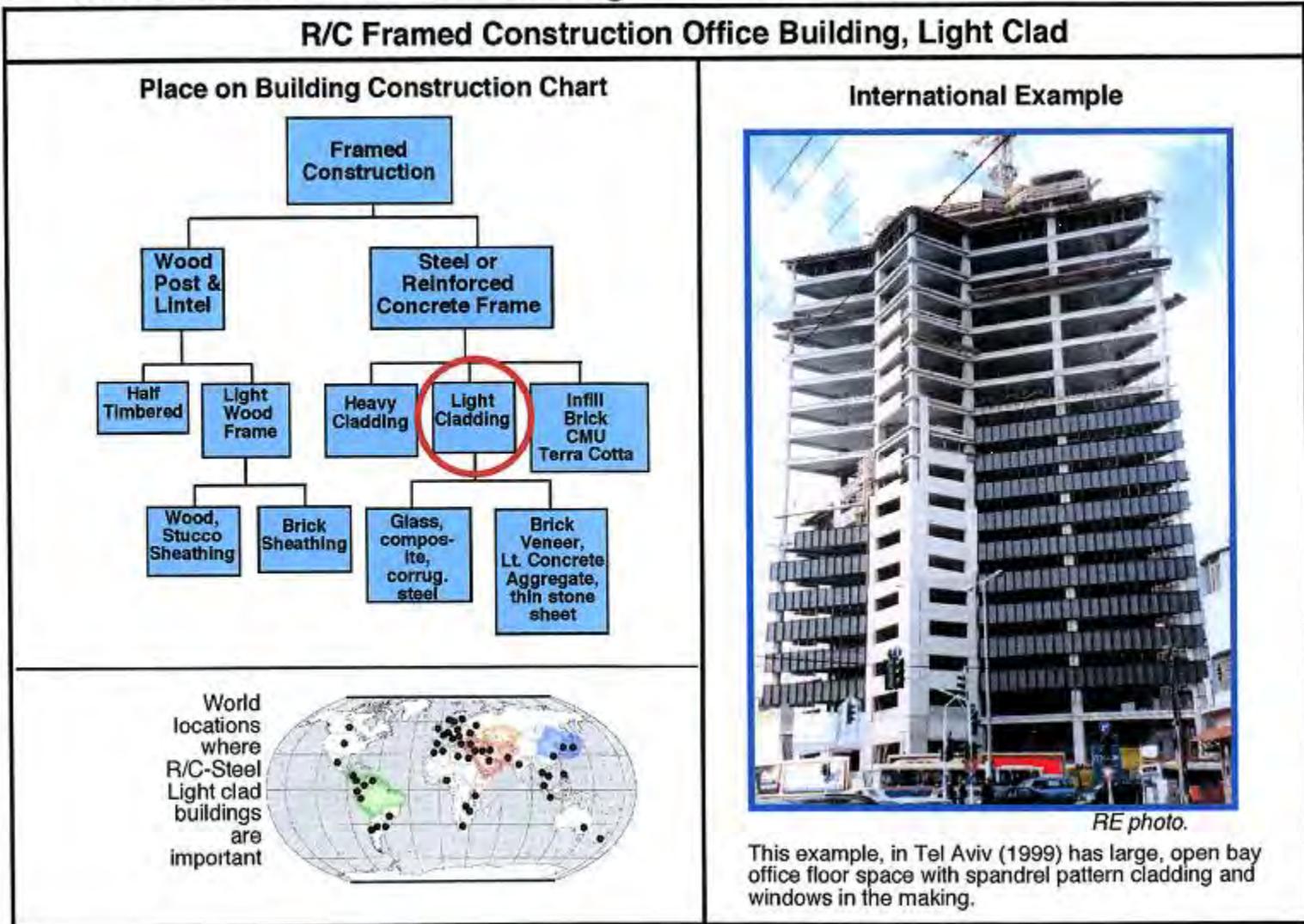
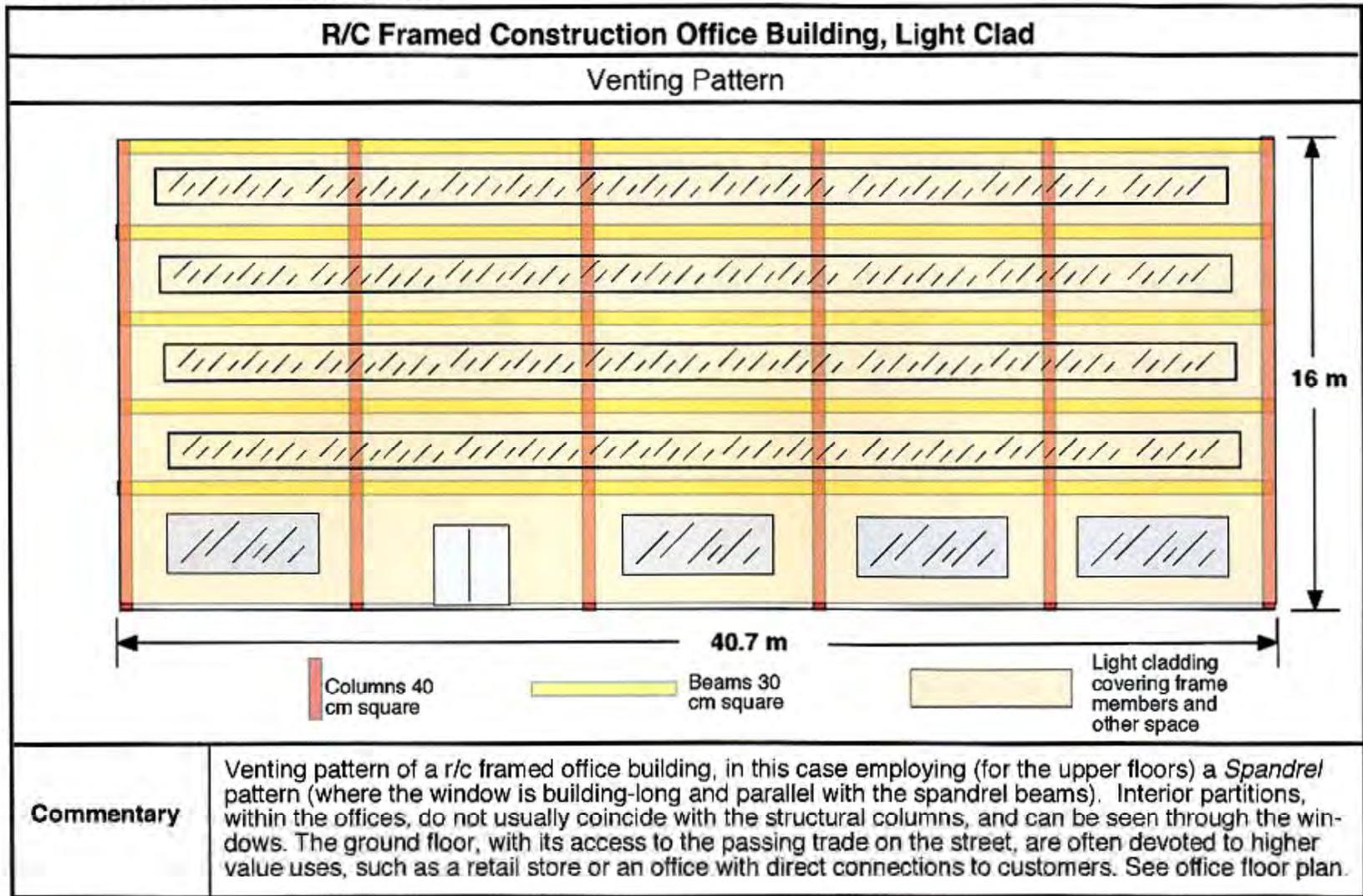


Figure 204. Framed 10-1 place on building construction chart.

Framed 10-2 Elevation



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Figure 205. Framed 10-2 elevation.

Framed 10-3-a Floor Plan

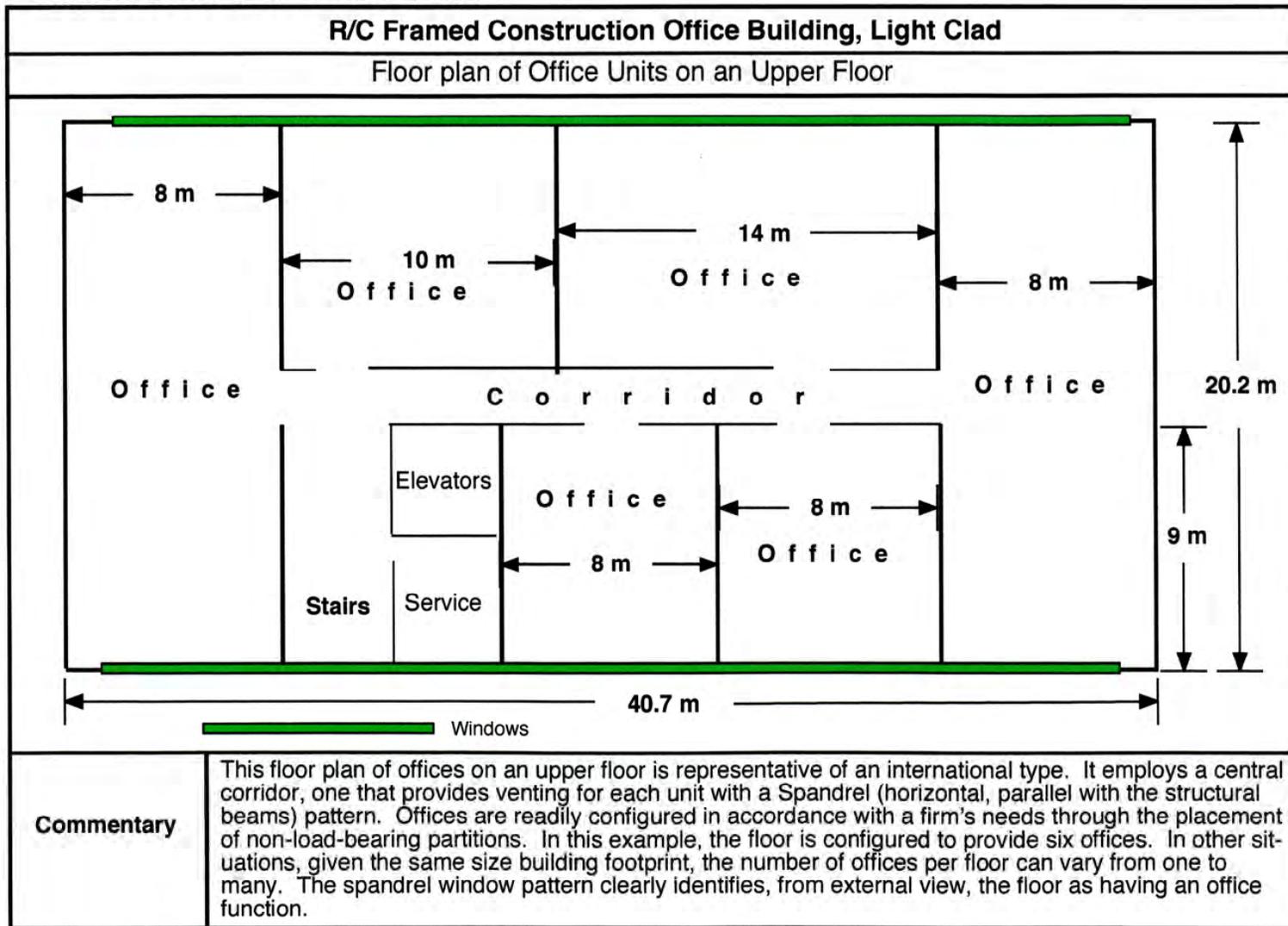
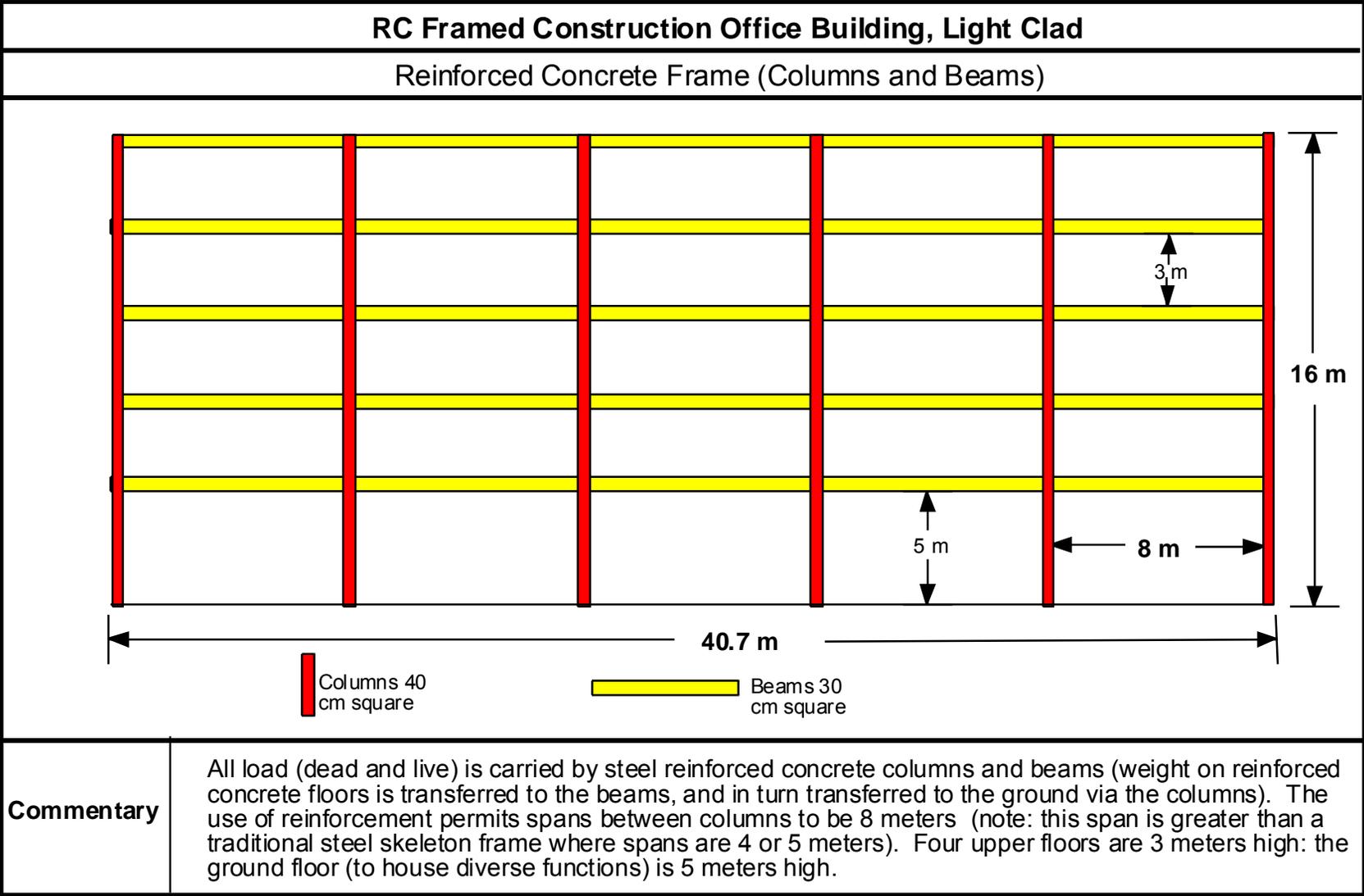


Figure 206. Framed 10-3-a floor plan.

Framed 10-4-a Construction



229

Figure 207. Framed 10-4-a construction.

Framed 10-4-b Construction

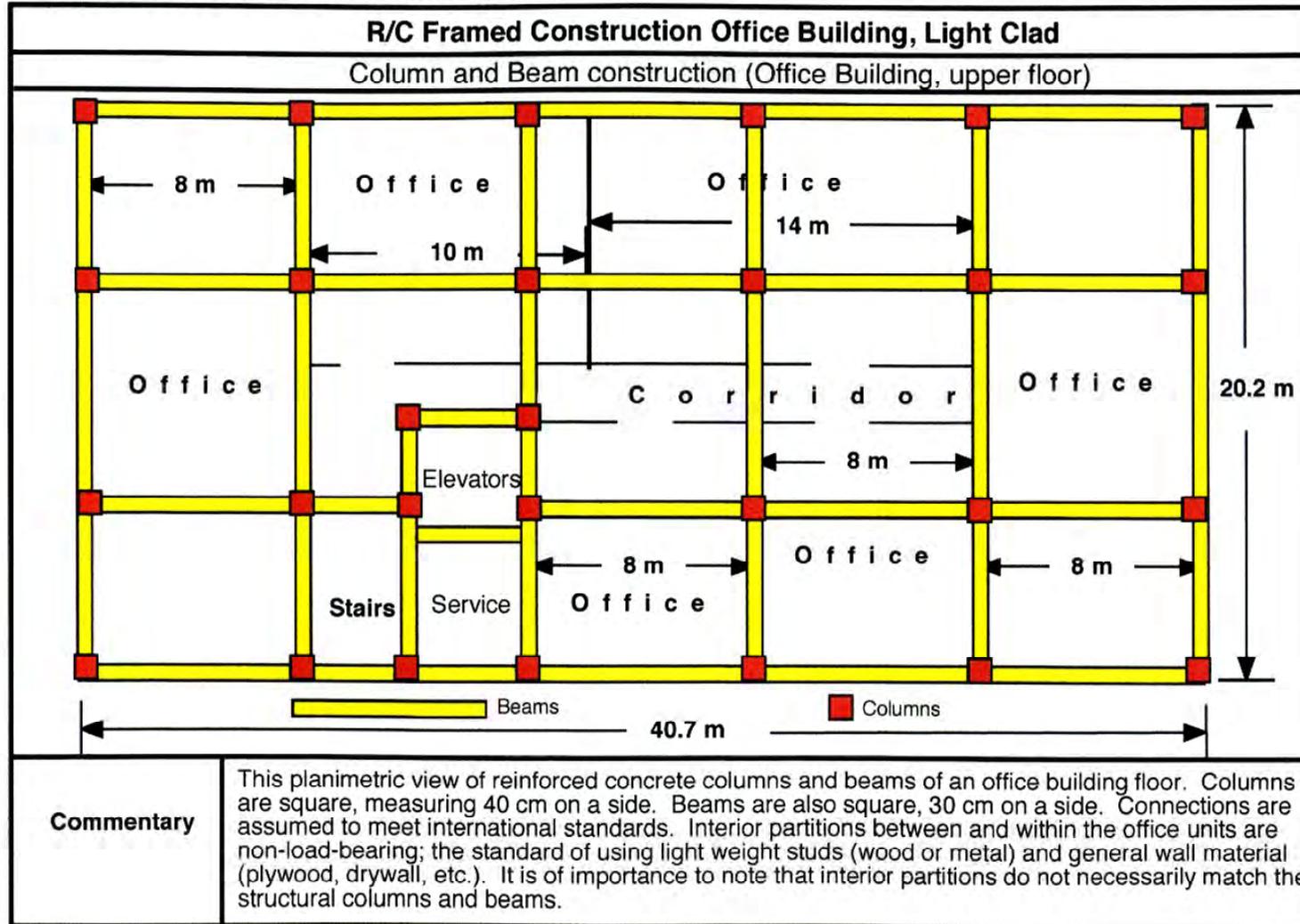


Figure 208. Framed 10-4-b construction.

Framed 11-1 Place on Building Construction Chart

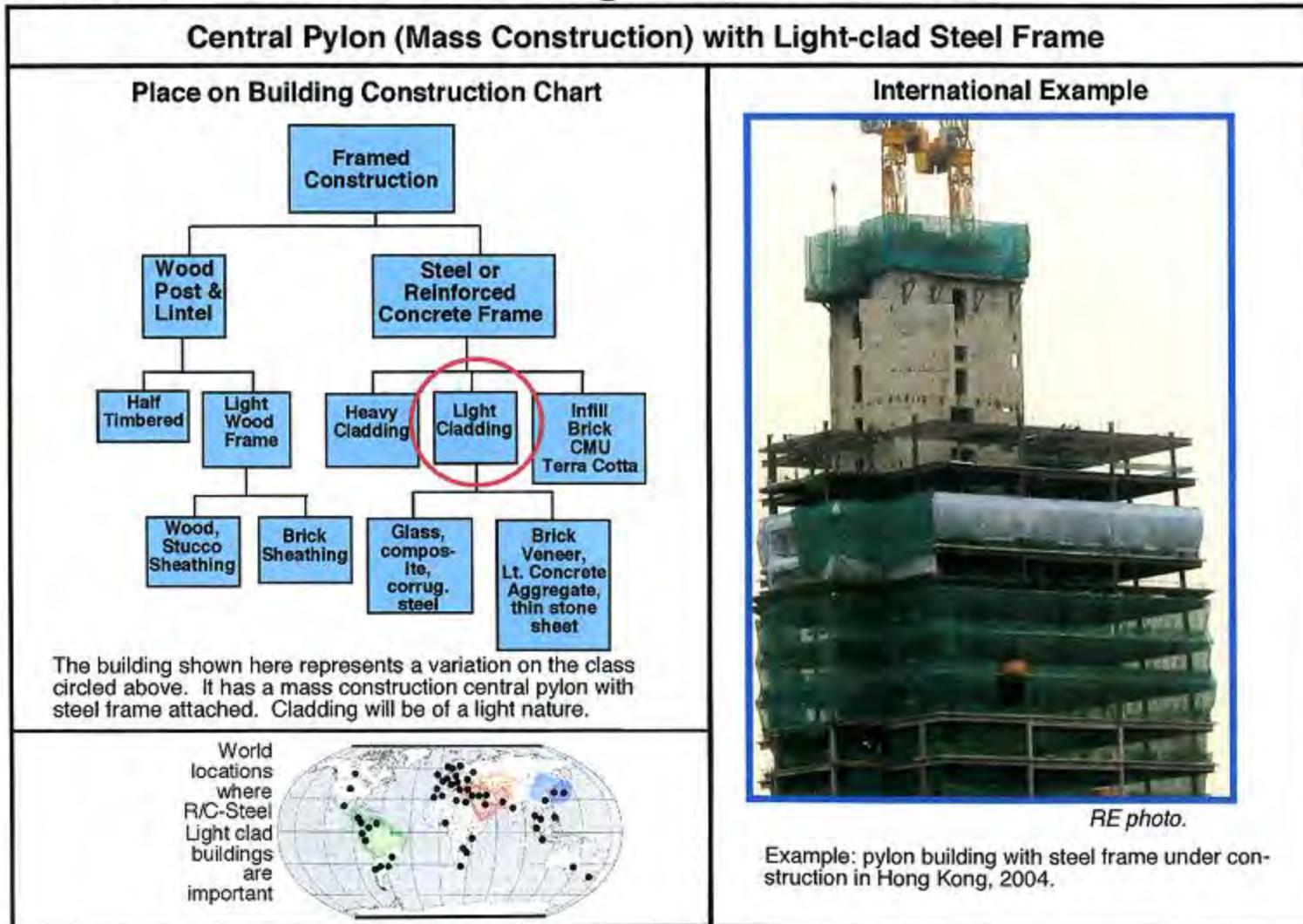
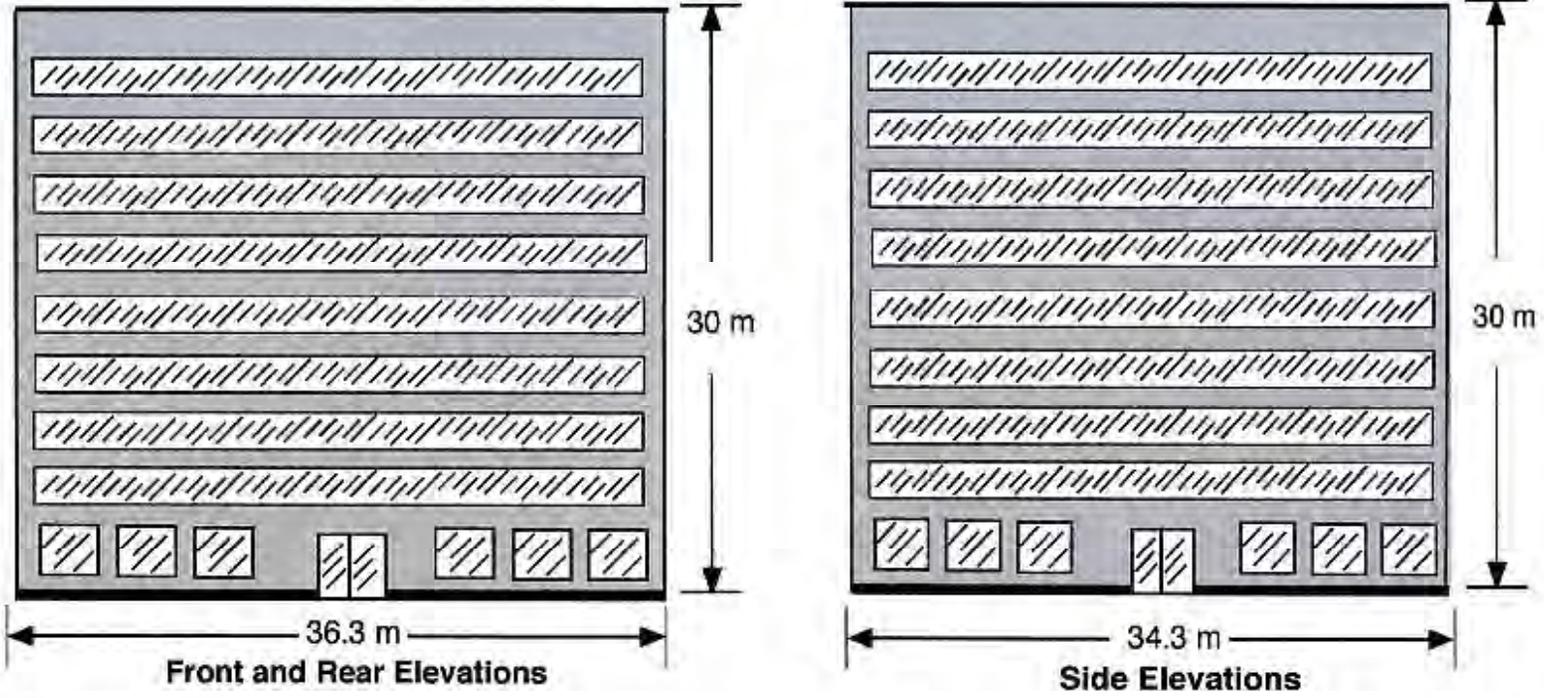


Figure 209. Framed 11-1 place on building construction chart.

Framed 11-2 Elevations

Central Pylon Office Building



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Commentary This example of a framed, light-clad office building, with its broad spandrel window pattern, has a very high proportion of windows to wall (53.2 % on the front and rear elevations and 51.1 % for the side elevations); the average for all framed light-clad structures is 34.3 %. The large windows on the ground floor contribute to the high proportions.

Figure 210. Framed 11-2 elevations.

Framed 11-3-a Floor Plan

Central Pylon (Mass Construction) with Light-clad Steel Frame

Commentary

The big advantage of central pylon/steel frame construction is its provision of large, column-free spaces, ones ideal for today's large corporation offices. Lightweight partitions are easily moved to customize space; a single corporation may occupy an entire floor or all floors, allowing the building to become a corporate icon. Sub-division of interior space on each floor, if done, is achieved through use of cubicles; management level offices are often partitioned with access to windows. The ground floor serves as entry to the elevators and, generally, is used for building security personnel and display.

Elevators, stairs, and restrooms are located in the central pylon.

Floor Plan An Upper Floor

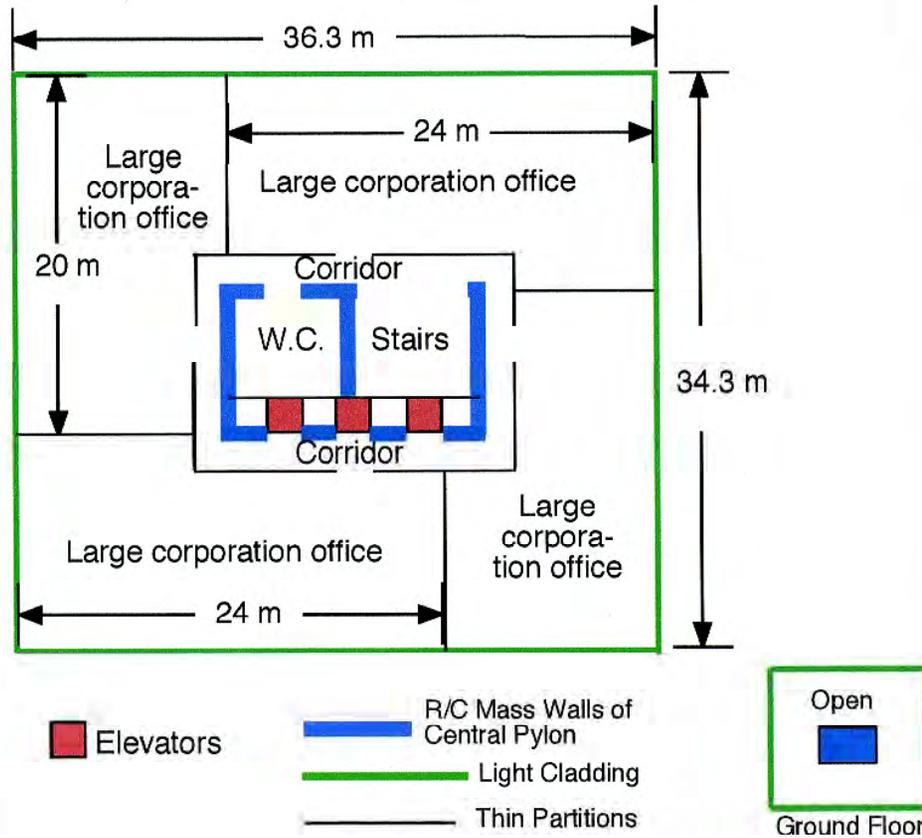


Figure 211. Framed 11-3-a floor plan.

Framed 11-4-a Construction

Central Pylon (Mass Construction) with Light-clad Steel Frame

Commentary

Central pylon/steel framed buildings form an example of both mass and framed construction in one structure. The reinforced concrete central pylon supports the steel frame members as the trunk of a tree supports its branches. It transfers loads from the beams of the steel frame to the ground. Walls of this central pylon are thick (usually about 30 cm) with rebar near the surfaces of both sides of each wall. It also serves as locale for services (elevators, stairways, W.C.s, and service modules). The long steel beams projecting outward from the central pylon enclose large spaces with but a sparse network of steel columns (far fewer than are seen in skeleton steel frame structures owing to the structural strength provided by the pylon).

Central Pylon and Steel Columns and Beams

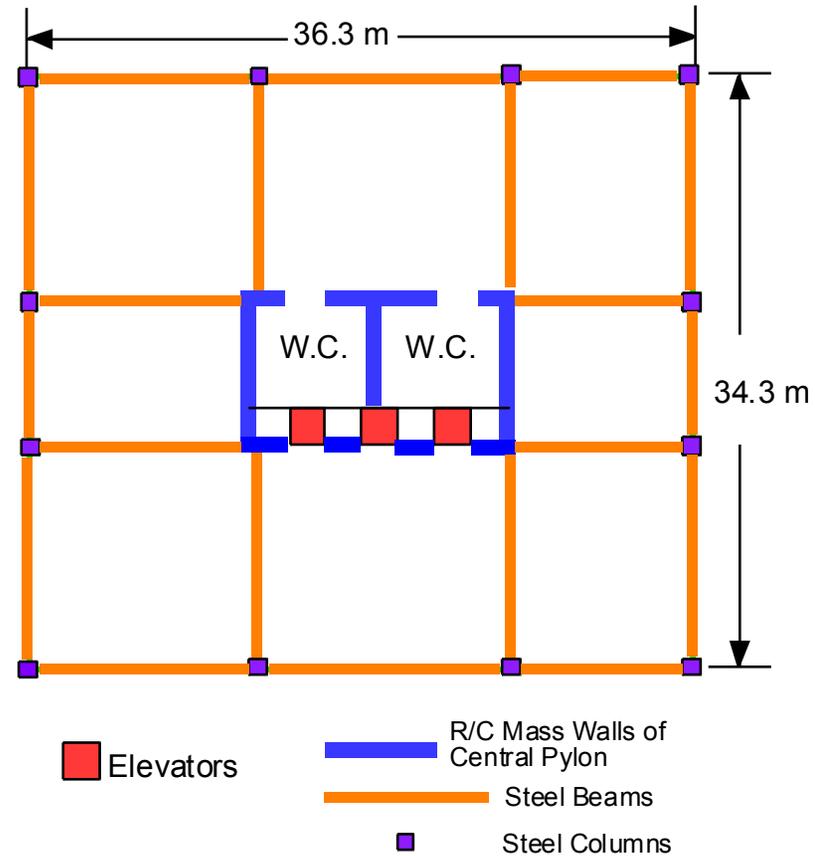


Figure 212. Framed 11-4-a construction.

Framed 11-4-b Construction

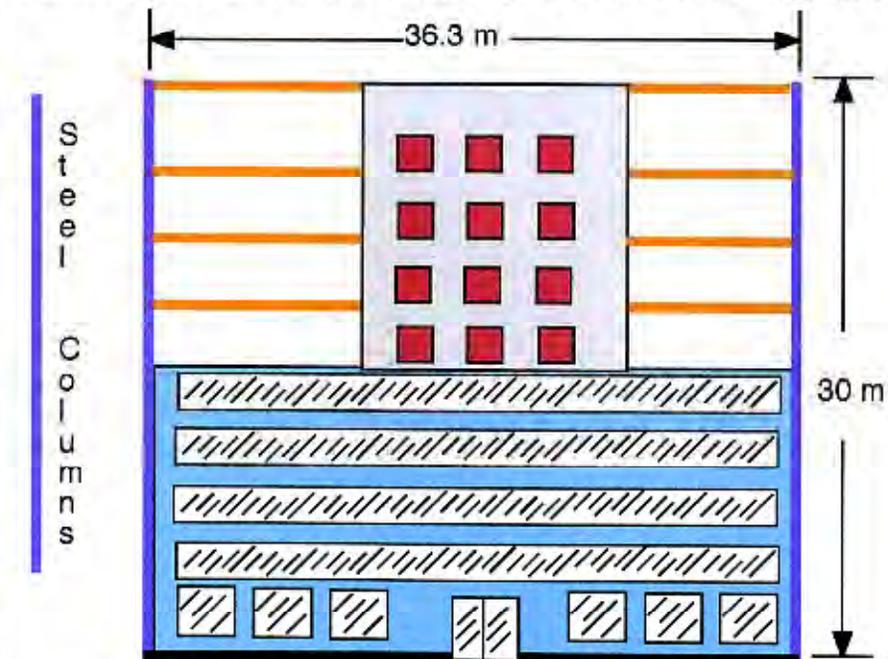
Central Pylon (Mass Construction) with Light-clad Steel Frame

Construction Process

Commentary

The anatomy of central pylon/steel frame construction is revealed in this demonstration of a building under construction. The common practice is to construct the central pylon first, using thick (30 cm) reinforced concrete walls to enclose elevators and service modules and to form an anchor for attaching steel beams. The construction process proceeds with the addition of the steel columns and beams. From the ground up, fireproofing is applied to the steel members. Cladding material and windows are then added. In this example, cladding and windows are finished about half way up the structure.

Central Pylon and Steel Columns and Beams Under Construction



Elevator openings in exposed central pylon



Exposed steel Beams



Cladding Material



Figure 213. Framed 11-4-b construction.

Framed 11-4-c Construction

Central Pylon (Mass Construction) with Light-clad Steel Frame

Construction details: pylon, frame, and floors



Central pylon building under construction in Tel Aviv, 1999. *RE photo.*



Beam connections and column/beam connections. *RE photo*



Support for corrugated steel floor. *RE photo*

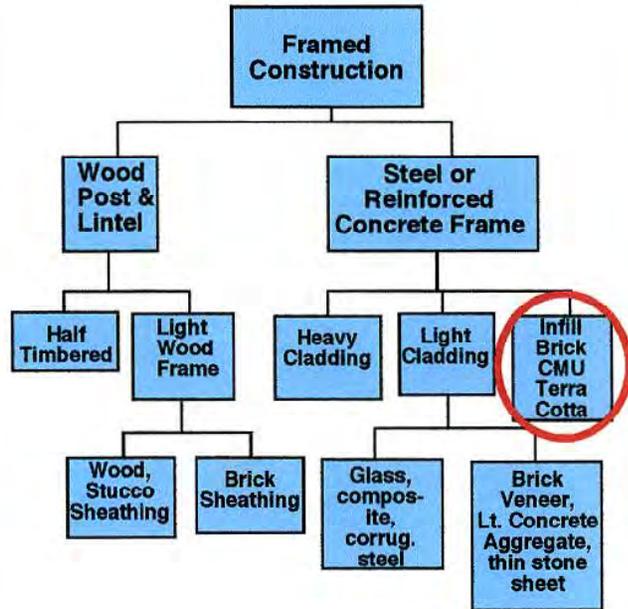
Commentary

The central pylon building, to the left, shows pouring concrete into forms in the pylon, erection of the frame, and placement of cladding and windows. Connection details are seen in the center photo. Support for the corrugated steel floor is seen on the right.

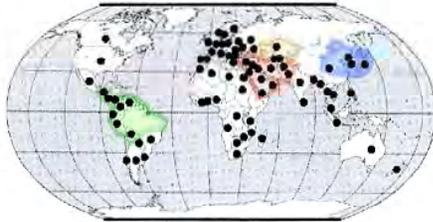
Framed 12-1 Place on Building Construction Chart

R/C Framed Construction House with Brick Infill Walls

Place on Building Construction Chart



World locations where R/C framed infill buildings are important



International Example



RE photo.

This unfinished structure, (near Luxor, Egypt, 2004), is typical of what is seen in much of the third world, a building under construction (and may have been so for some time). The rebar juts out of the columns possibly anticipating another floor later. Brick infill is double brick. The r/c beams and columns are crude and probably larger than necessary. Sub-standard concrete strength may be responsible.

Figure 215. Framed 12-1 place on building construction chart.

Framed 12-2-a Elevation

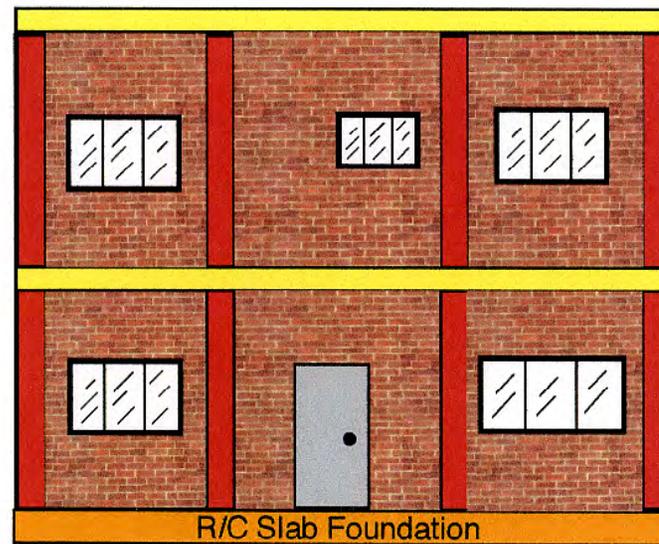
R/C Framed Construction House with Brick Infill Walls

Commentary

Non-load-bearing Brick infill walls between columns and beams is two bricks thick (23 cm).

Upon completion of building, bricks are commonly covered with a coating of stucco (usually about 2 to 3 cm thick).

Front Elevation Brick Infill



Beams

Columns

Figure 216. Framed 12-2-a elevation.

Framed 12-2-b Elevation

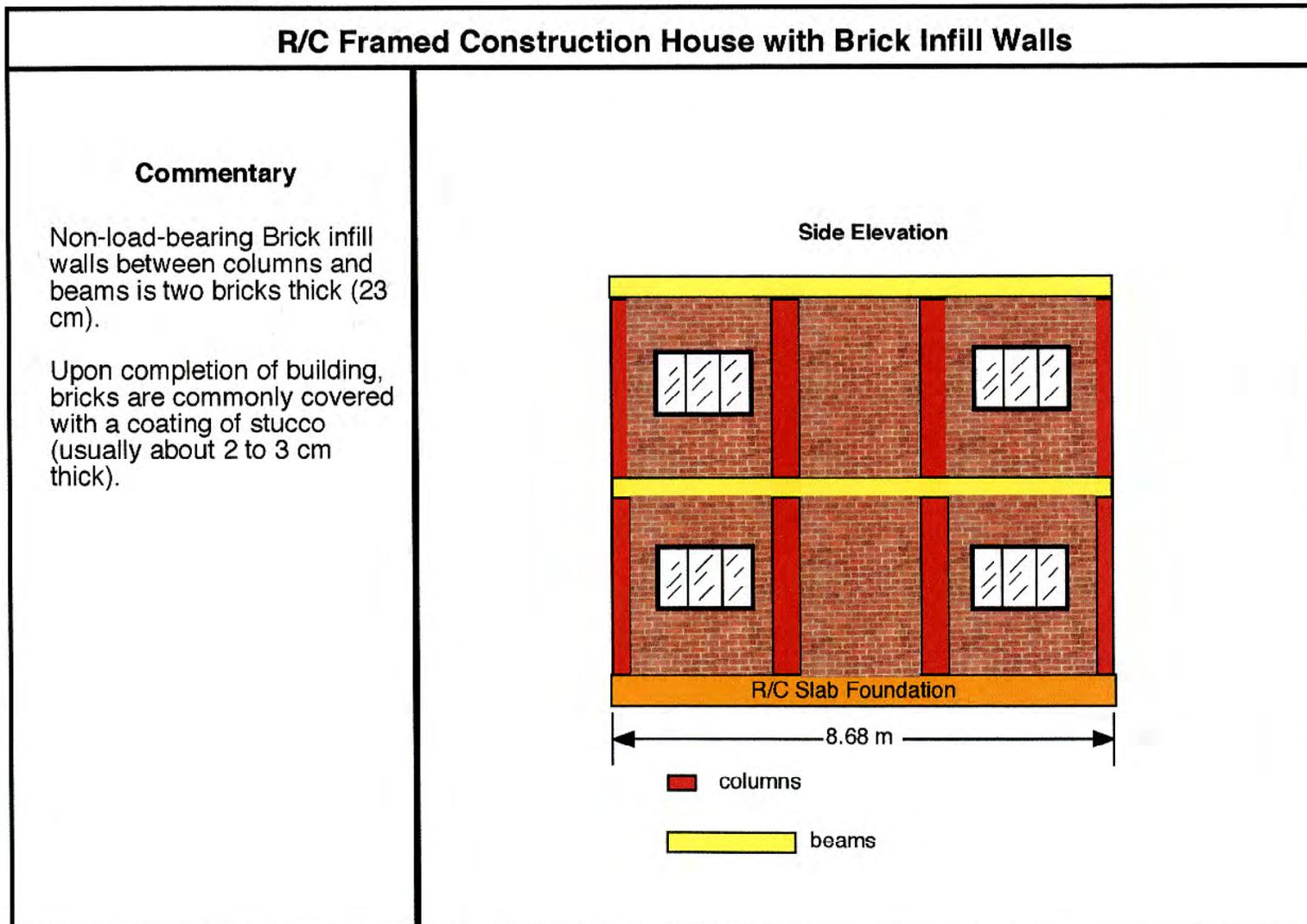


Figure 217. Framed 12-2-b elevation.

Framed 12-3-a Floor Plan

R/C Framed Construction House with Brick Infill Walls

Floor Plan (Ground floor of a 2 story house)

Commentary

While variations on the floor plan given here are infinite, this plan serves as a generic composite. It takes into consideration dimensions of rooms, corridor, doorways, and windows that have a human scale, based on standard sizes of furniture and living space needs.

This ground floor plan has rooms, in appropriate sizes, required to meet common daily needs: living and family eating areas are joined; the dining area can be served by the kitchen; utility needs are met by a small utility room; the kitchen is of modest but adequate size. Entry hall and stairway meet common needs.

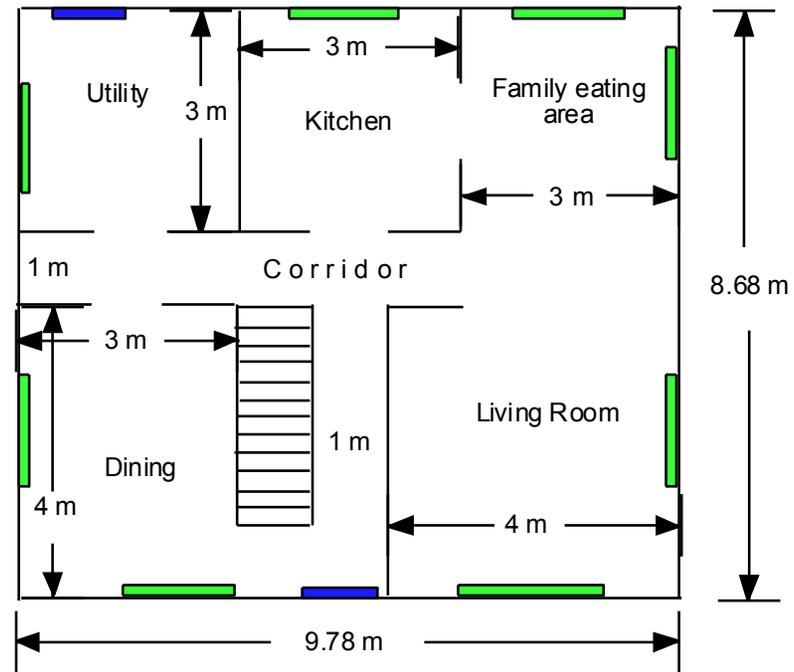


Figure 218. Framed 12-3-a floor plan.

Framed 12-3-b Floor Plan

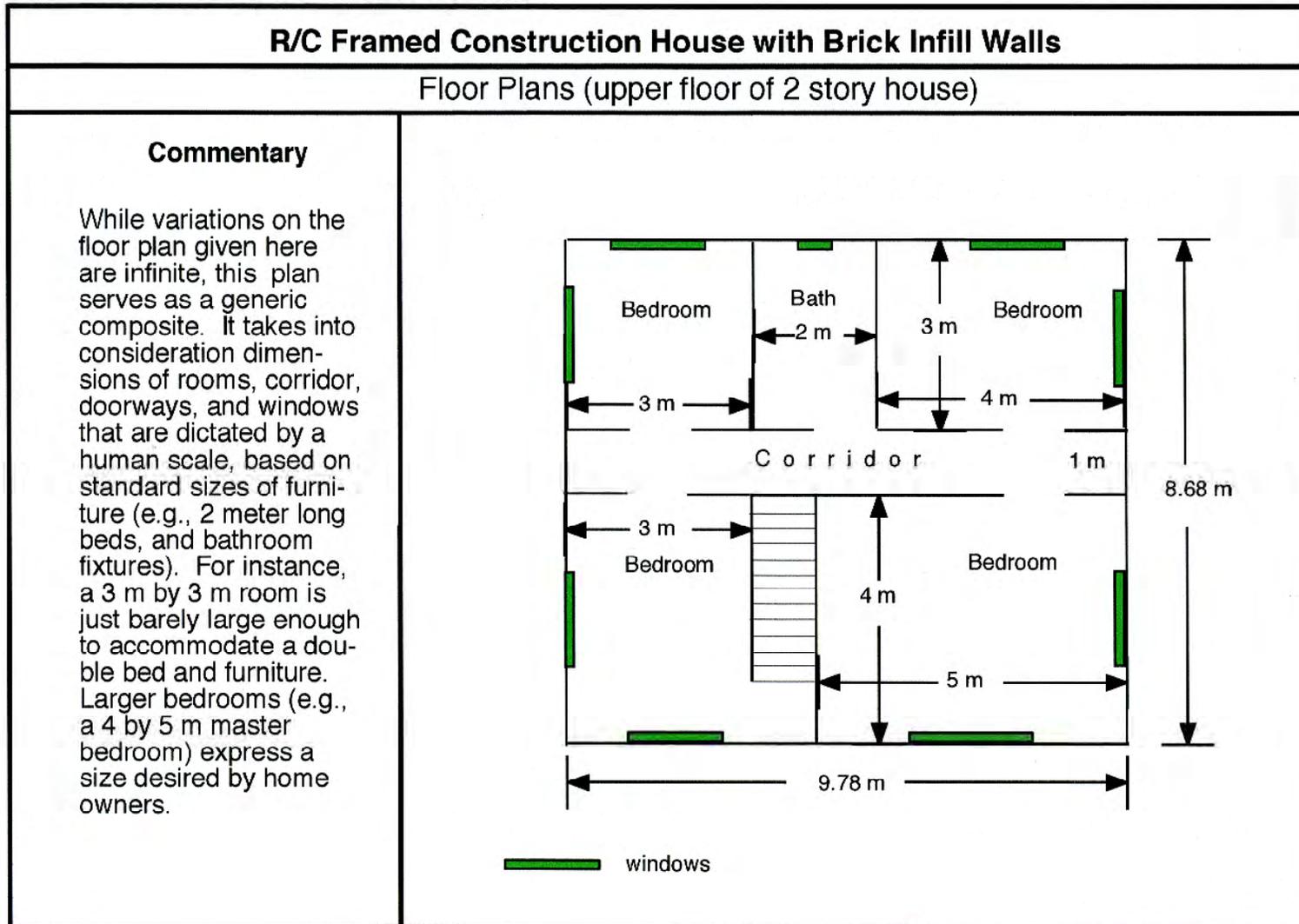


Figure 219. Framed 12-3-b floor plan.

Framed 12-4-a Construction

R/C Framed Construction House with Brick Infill Walls

Commentary

This front elevation view of the ground floor of a reinforced concrete framed house shows the arrangement of the r/c columns and beams.

Columns measure 25 cm by 40 cm. The wide side of the beams are parallel with the face of the exterior walls.

Beams are square, measuring 30 cm by 30 cm. In the construction process, poured concrete beams are placed on the columns extending upward from the ground floor. The process is then repeated for upper floors.

R/C floors are connected to the beams with tied rebar.

Front Elevation

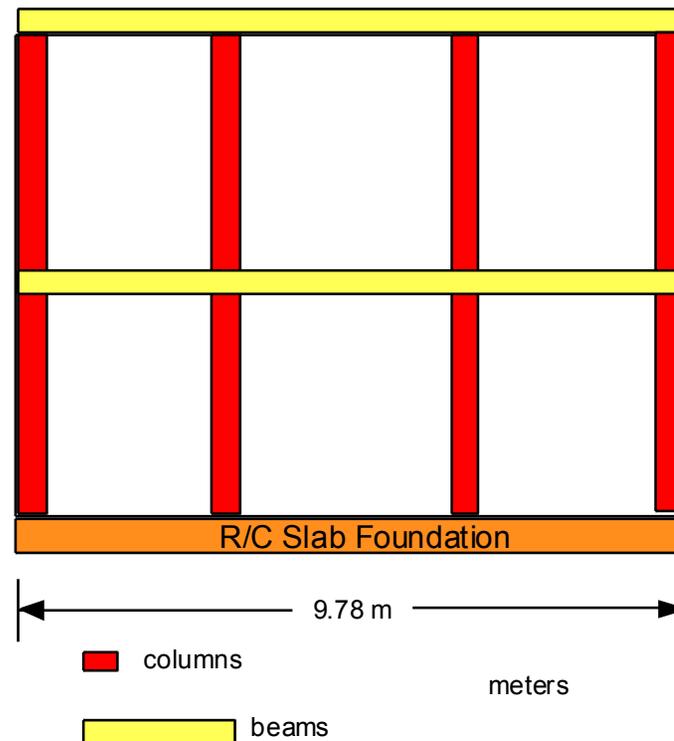


Figure 220. Framed 12-4-a construction.

Framed 12-4-b Construction

R/C Framed Construction House with Brick Infill Walls

Commentary

This side elevation view of the ground floor of a reinforced concrete framed house shows the arrangement of the r/c columns and beams.

Columns measure 25 cm by 40 cm. The wide side of the beams are parallel with the face of the exterior walls.

Beams are square, measuring 30 cm by 30 cm.

R/C floors are connected to the beams with tied rebar.

Side Elevation

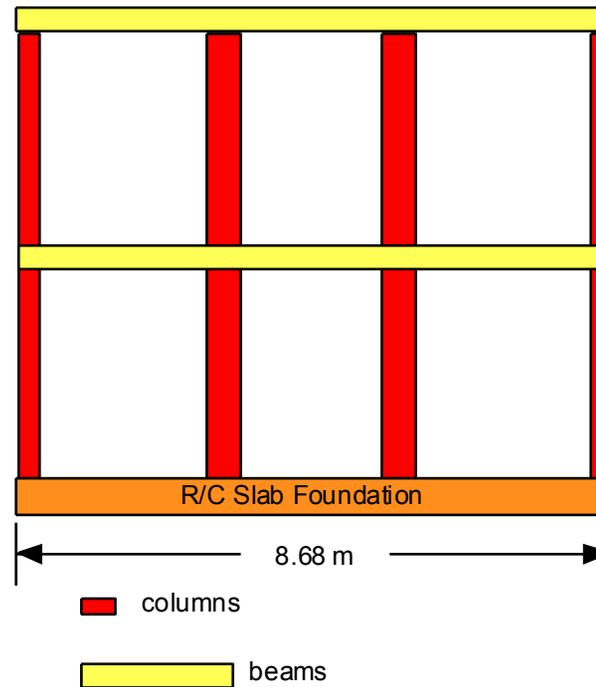


Figure 221. Framed 12-4-b construction.

Framed 12-4-c Construction

R/C Framed Construction House with Brick Infill Walls

Column and Beam construction (Ground floor of a 2 story house)

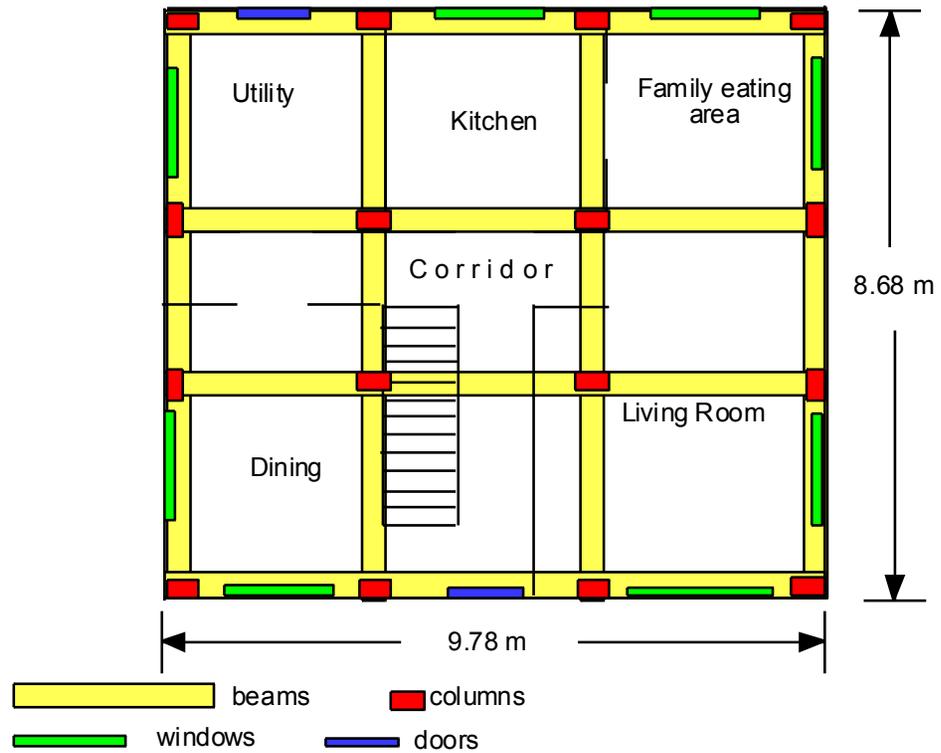
Commentary

This planimetric view of the ground floor of a reinforced concrete framed house (with various infill material) shows the arrangement of the r/c columns and beams.

Columns measure 25 cm by 40 cm. The wide side of the beams are parallel with the face of the exterior walls.

Beams are square, measuring 30 cm by 30 cm.

Planimetric View



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Figure 222. Framed 12-4-c construction.

Framed 12-4-d Construction

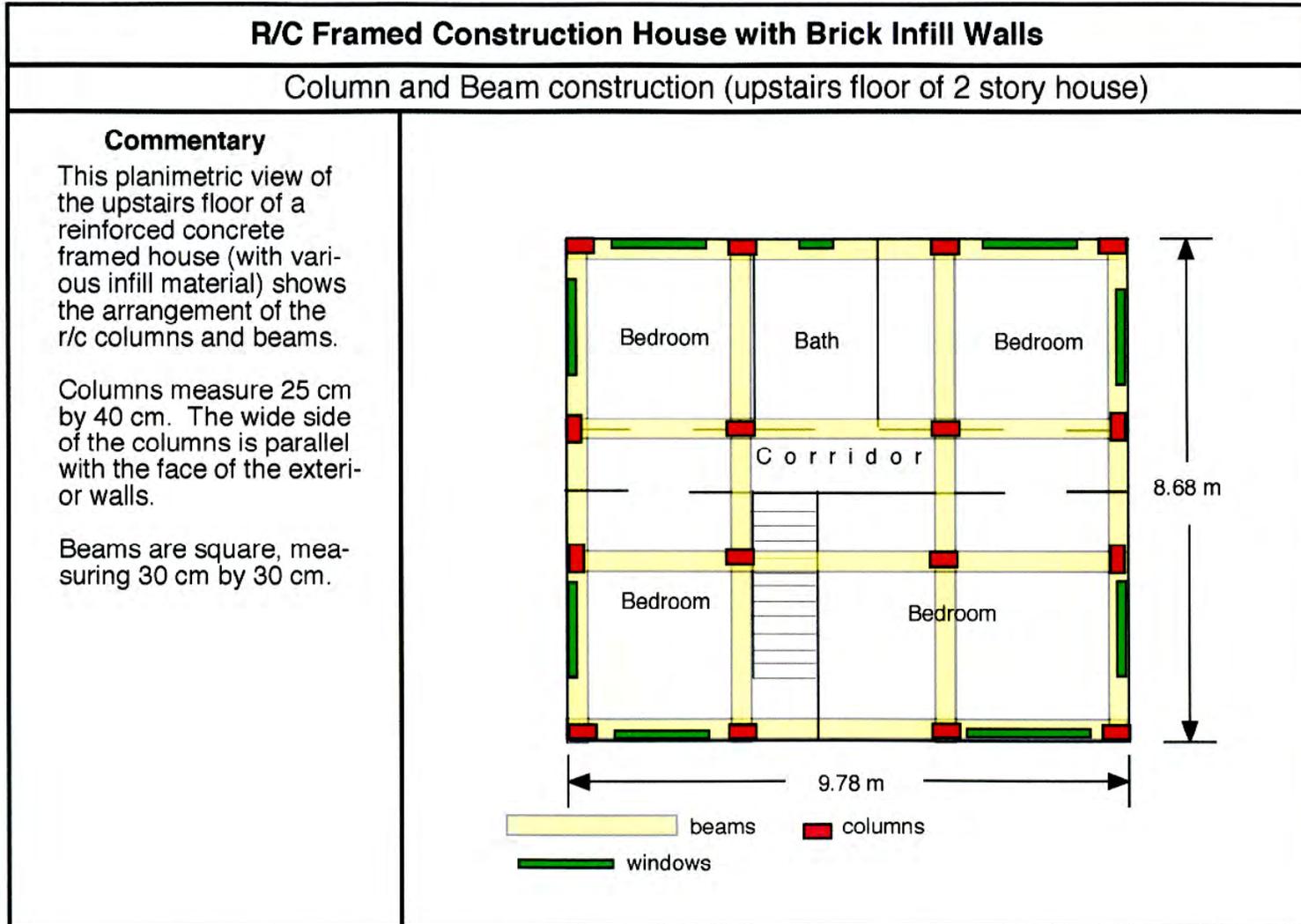
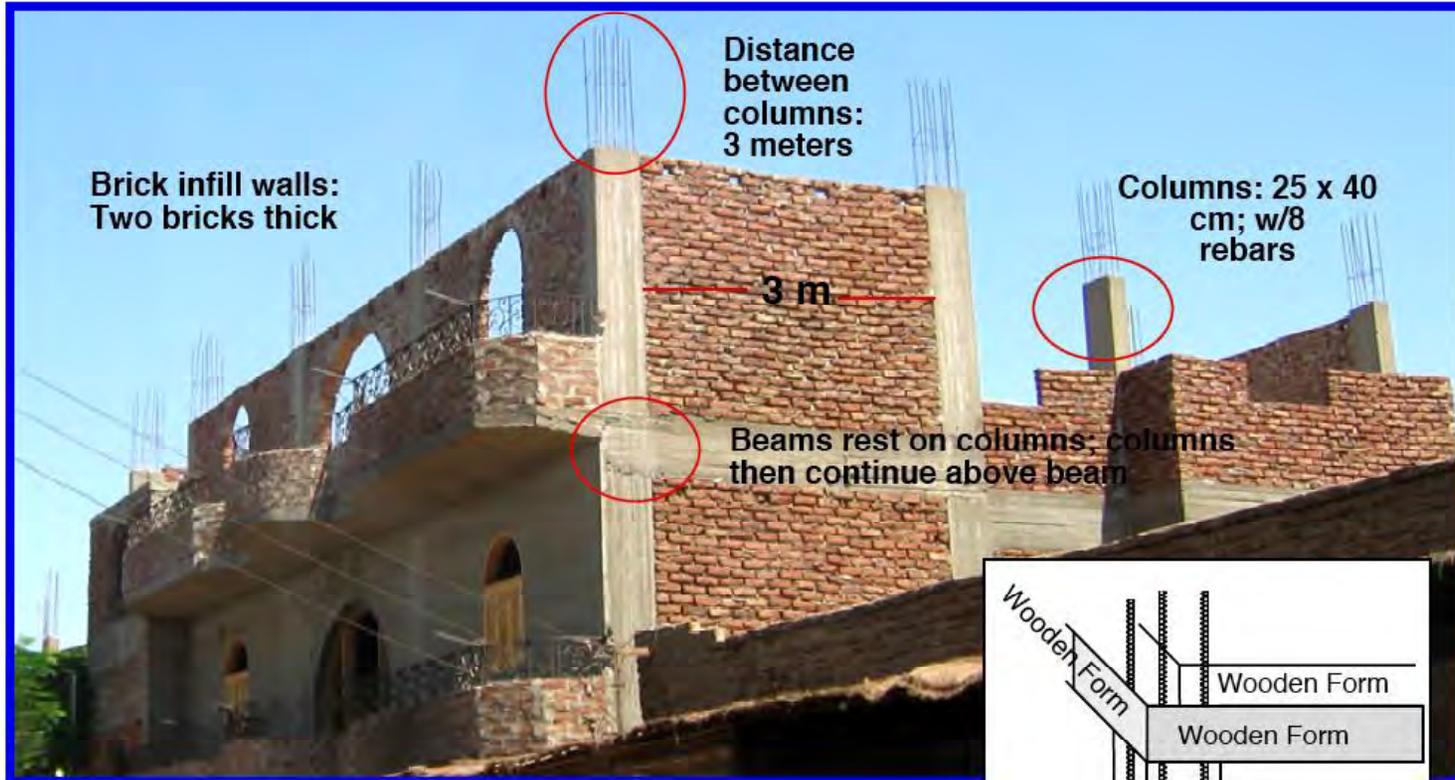


Figure 223. Framed 12-4-d construction.

Framed 12-4-e Construction

Construction details of a Reinforced Concrete framed house with brick (non-load-bearing) infill walls



Typical building of this type in Luxor, Egypt RE Photo

Procedure in building frame: Rebar is positioned in columns. Beams are poured around rebar in form and rest on column. Process is repeated with each new story.

Figure 224. Framed 12-4-e construction.

Framed 12-4-f Construction

Details on R/C column and Double
Brick Infill Wall: Luxor, Egypt, 2004

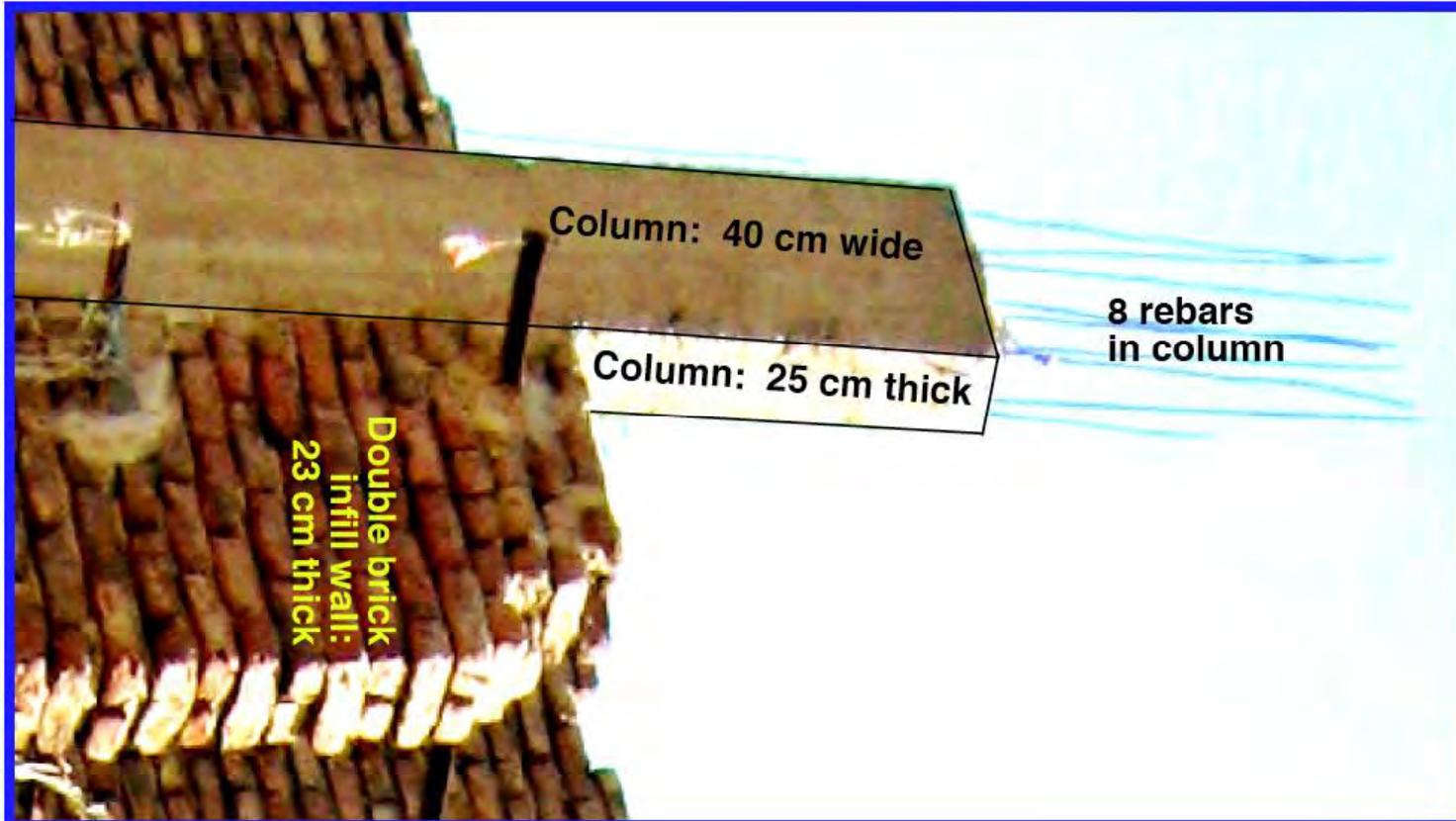


Figure 225. Framed 12-4-f construction.

Framed 13-1 Place on Building Construction Chart

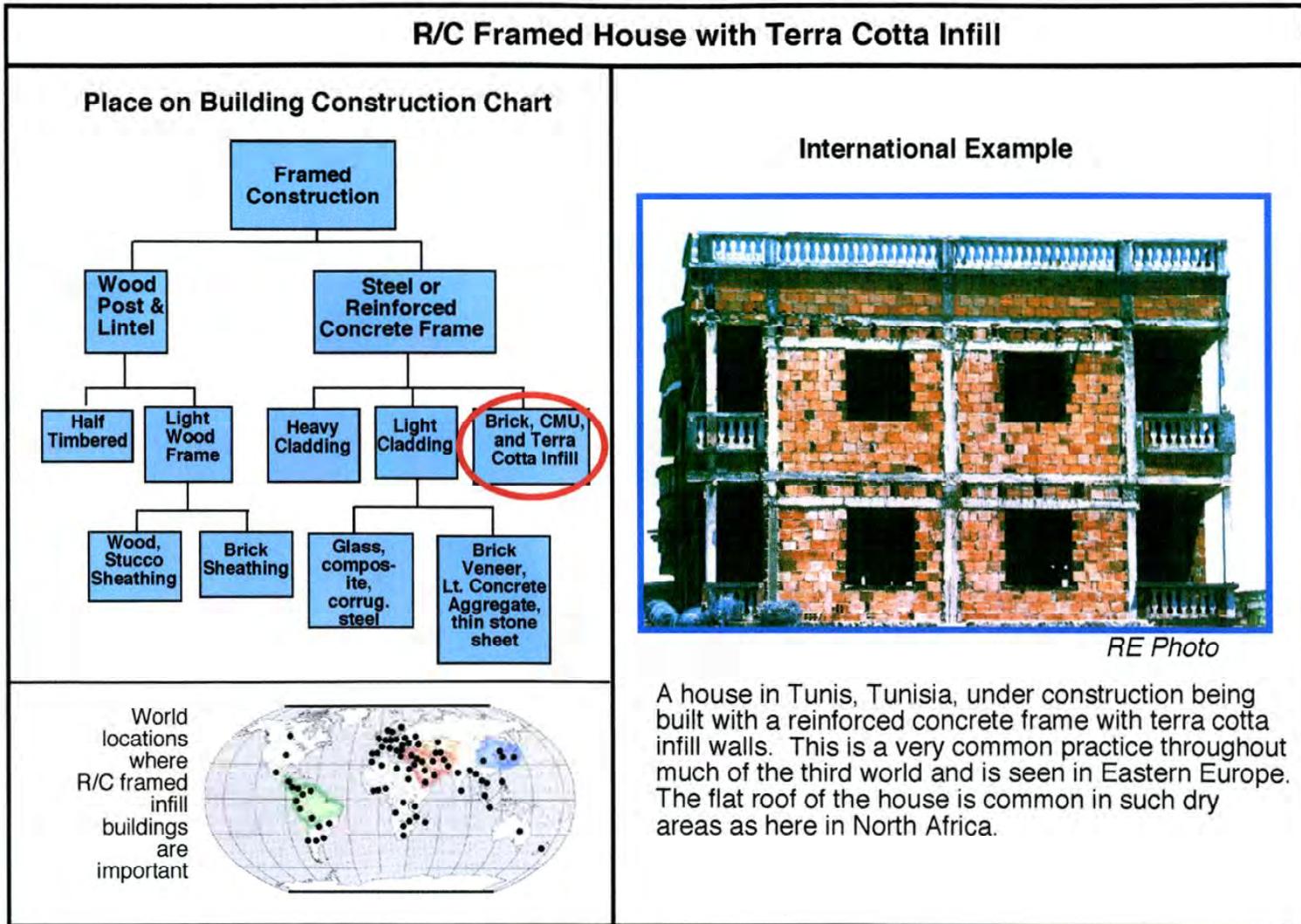


Figure 226. Framed 13-1 place on building construction chart.

Framed 13-2-a Elevation

R/C Framed House with Terra Cotta Infill

Commentary

Non-load-bearing Terra Cotta infill walls between columns and beams is one terra cotta block thick. (Terra cotta blocks measure 40 cm by 25 cm x 25 cm).

Upon completion of building, terra cotta blocks are commonly covered with a coating of stucco (usually about 2 to 3 cm thick).

Front Elevation Terra Cotta Block Infill

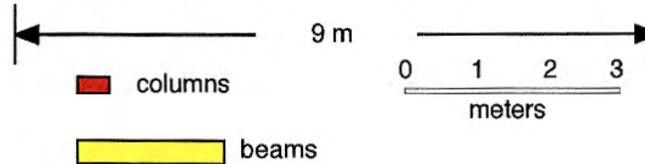
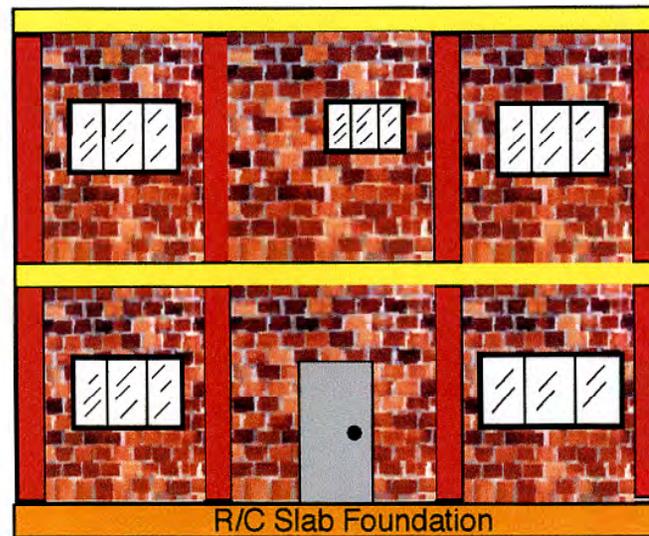


Figure 227. Framed 13-2-a elevation.

Framed 13-2-b Elevation

R/C Framed House with Terra Cotta Infill

Commentary

Non-load-bearing Terra Cotta infill walls between columns and beams is one terra cotta block thick. (Terra cotta blocks measure 40 cm by 25 cm x 25 cm).

Upon completion of building, terra cotta blocks are commonly covered with a coating of stucco (usually about 2 to 3 cm thick).

Side Elevation Terra Cotta Block Infill

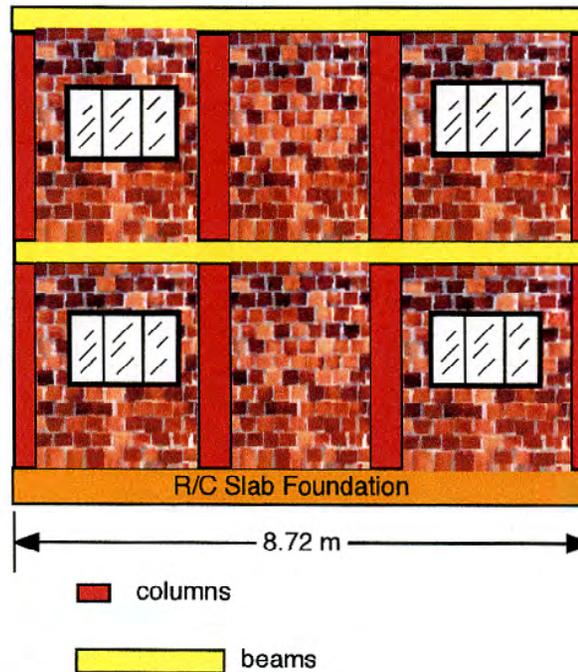


Figure 228. Framed 13-2-b elevation.

Framed 13-3-a Floor Plan

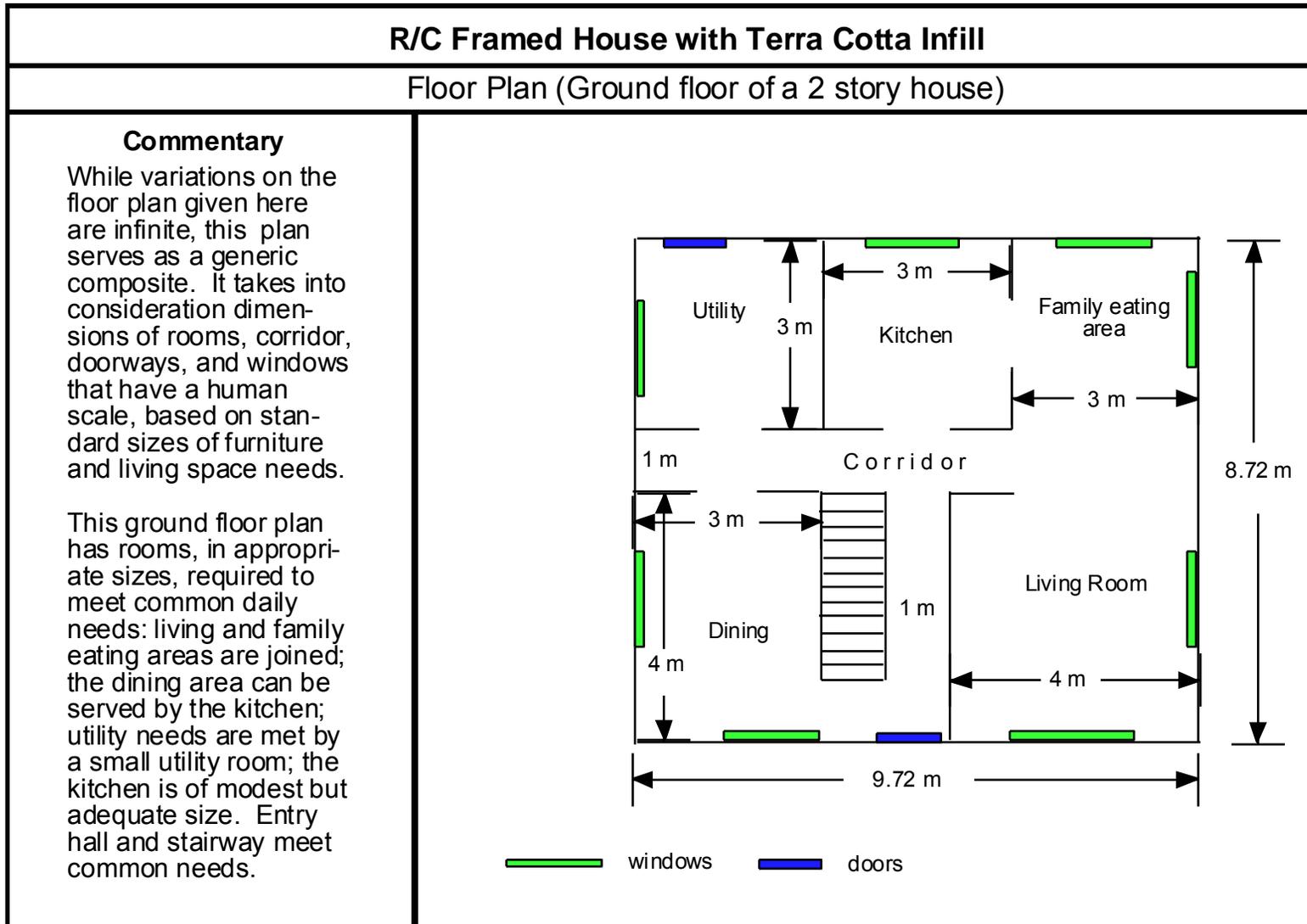


Figure 229. Framed 13-3-a floor plan.

Framed 13-3-b Floor Plan

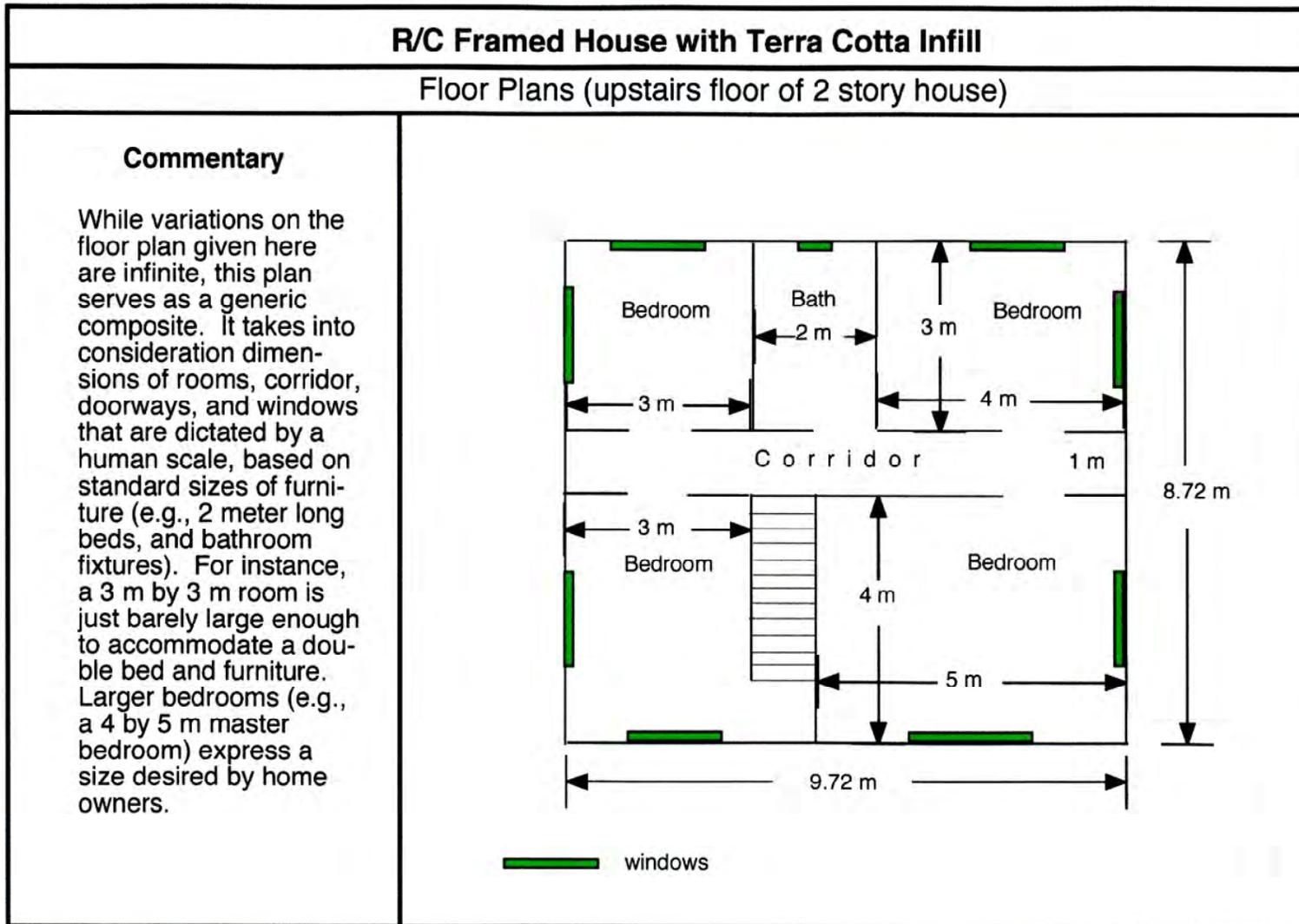


Figure 230. Framed 13-3-b floor plan.

Framed 13-4-a Construction

R/C Framed House with Terra Cotta Infill

Column and Beam construction (Ground floor of a 2 story house)

Commentary

This planimetric view of the ground floor of a reinforced concrete framed house (with terra cotta infill material) shows the arrangement of the r/c columns and beams.

Columns measure 25 cm by 40 cm. The wide side of the beams are parallel with the face of the exterior walls.

Beams are square, measuring 30 cm by 30 cm.

Planimetric View

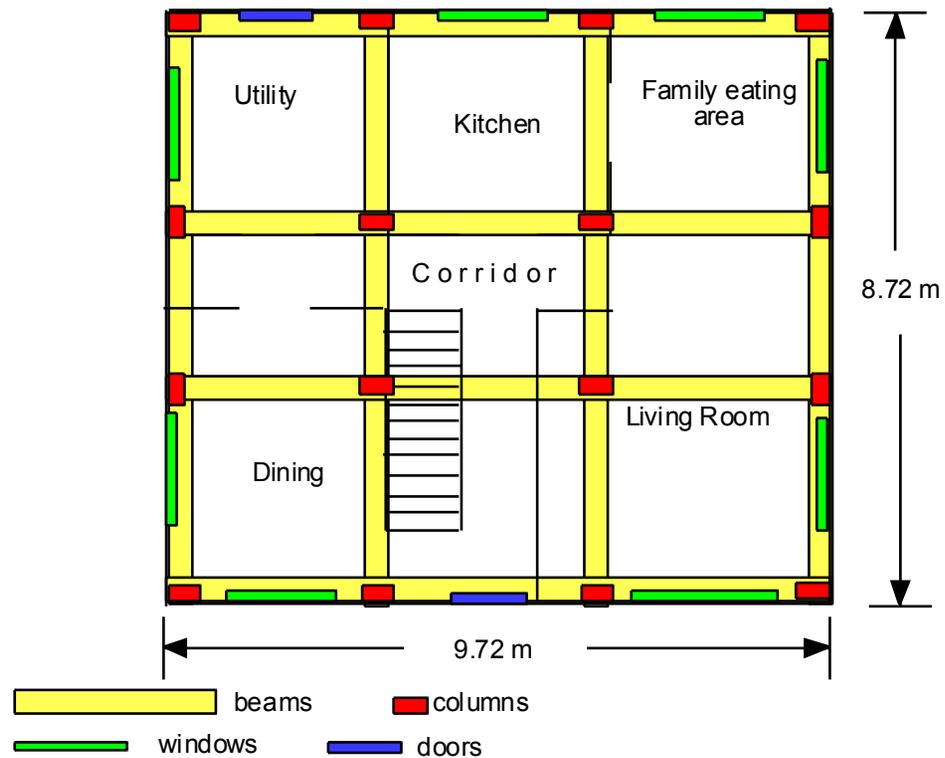
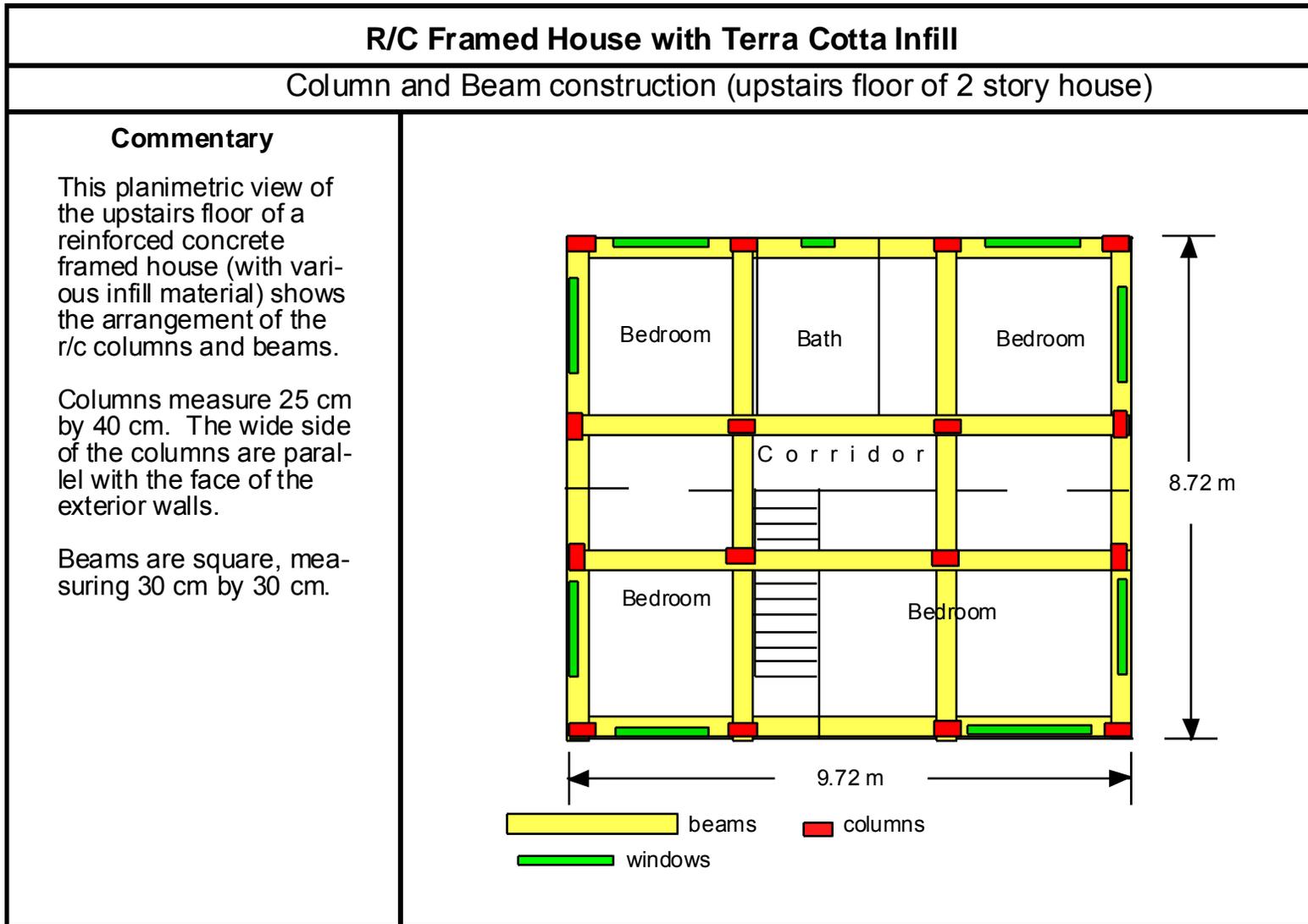


Figure 231. Framed 13-4-a construction.

Framed 13-4-b Construction



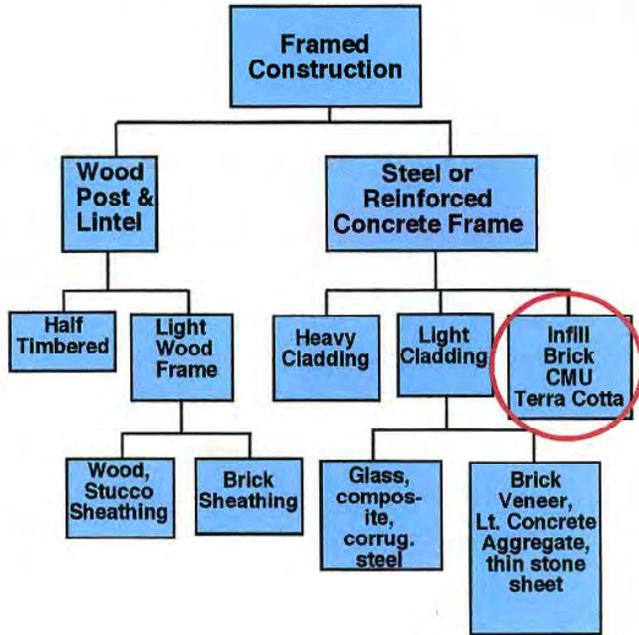
254

Figure 232. Framed 13-4-b construction.

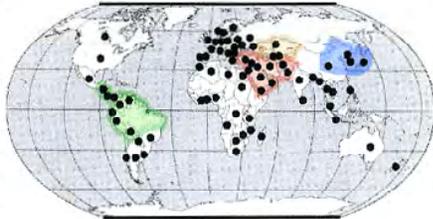
Framed 14-1 Place on Building Construction Chart

R/C Framed Construction with CMU Infill Walls; Retail/Residential

Place on Building Construction Chart



World locations where R/C framed infill buildings are important



International Example

Typical reinforced concrete frame with concrete block infill

San José, Costa Rica (1994)



RE photo

Reinforced concrete framed buildings with CMU infill blocks are very common worldwide and especially in countries where economic development is recent.

Figure 233. Framed 14-1 place on building construction chart.

Framed 14-2-a Elevation

R/C Framed Construction with CMU Infill Walls; Retail/Residential

Construction Method and Dimensions

Commentary

This front elevation shows the different venting (windows and door) for the two floors; the retail store on the ground floor has large display windows and a central door. The residence above has typical smaller windows; the entrance to the unit is at the rear.

Concrete frame members, columns and beams appear in red. An example of the CMU infill blocks is seen on the ground floor. CMU blocks, in finished buildings, are ordinarily covered by stucco to protect them from the elements.

Front Elevation

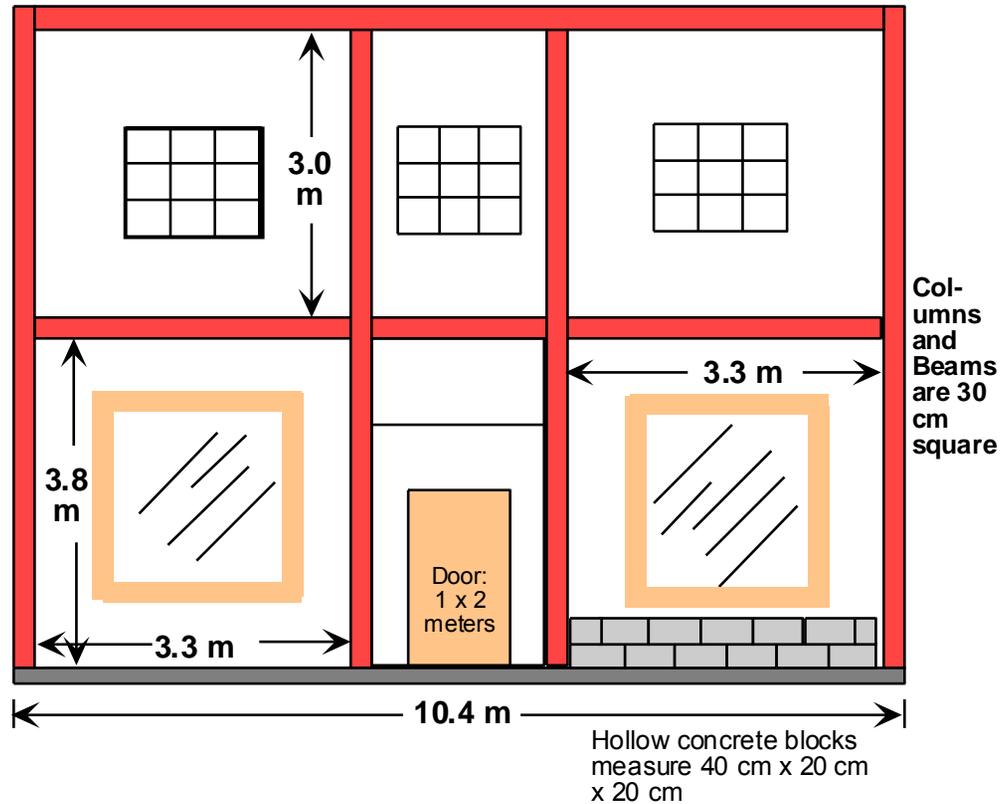


Figure 234. Framed 14-2-a elevation.

Framed 14-2-b Elevation

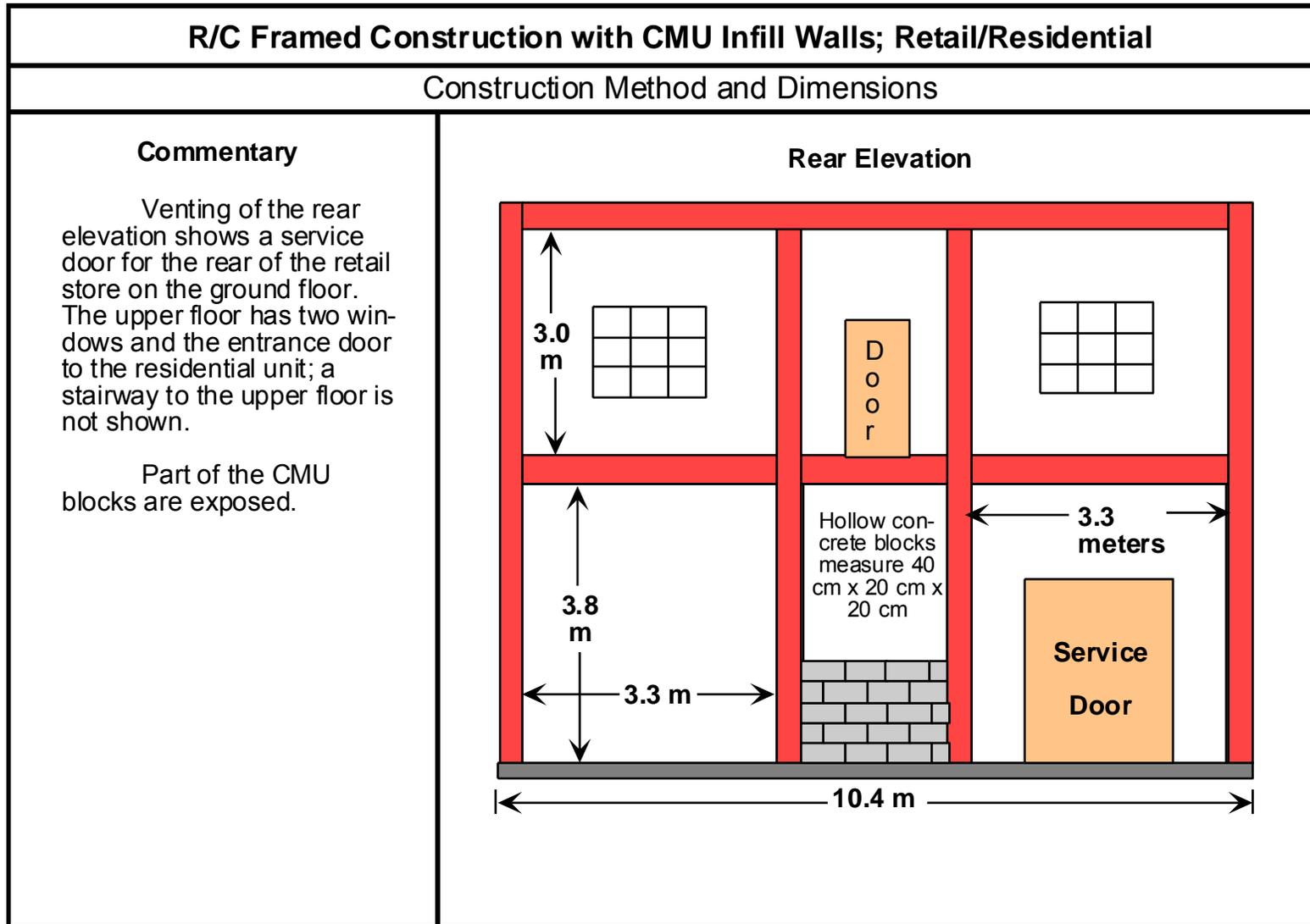


Figure 235. Framed 14-2-b elevation.

Framed 14-3-a Floor Plan

R/C Framed Construction with CMU Infill Walls; Retail/Residential

Floor Plan and Isometric: Ground Floor (Retail)

Commentary

Ground level retail establishments, such as shown here, will normally be longer than they are wide, and will have space devoted to inventory storage and other business functions in the rear of the building, and will have a wide access door. Retail space will be without partitions, although columns are exposed, and will have wide doors and large windows.

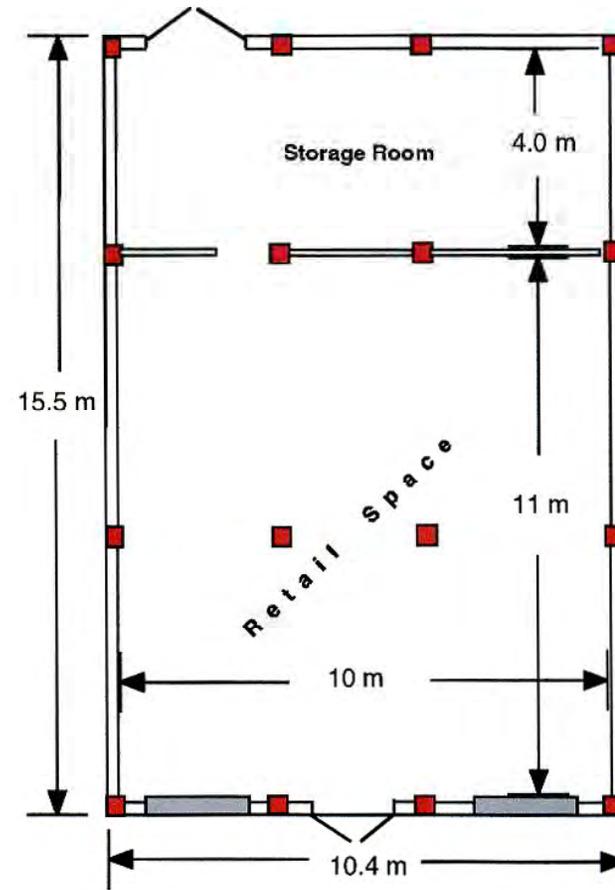
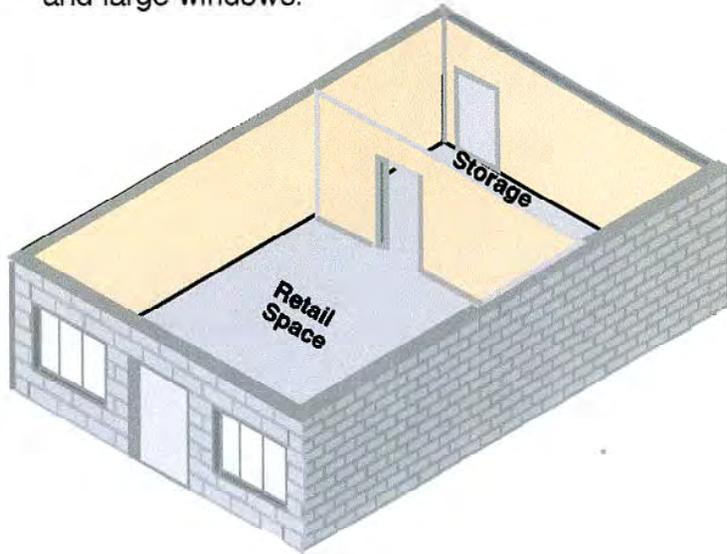


Figure 236. Framed 14-3-a floor plan.

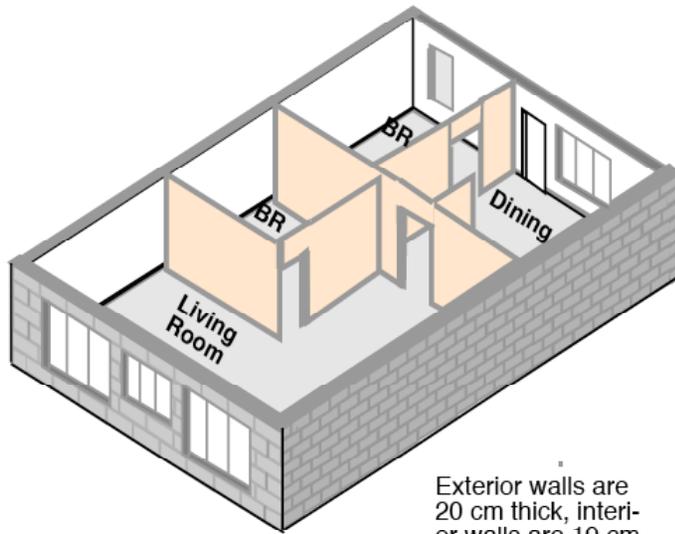
Framed 14-3-b Floor Plan

R/C Framed Construction with CMU Infill Walls; Retail/Residential

Floor Plan and Isometric: Upper Floor (Residential)

Commentary

Residential floor is divided into rooms by partitions one 10 cm CMU block thick. Windows are only on front and rear faces, as is typical of such long rectangle footprints. Answering concerns about collateral damage, the unit shown here would house a family of four.



Exterior walls are 20 cm thick, interior walls are 10 cm.

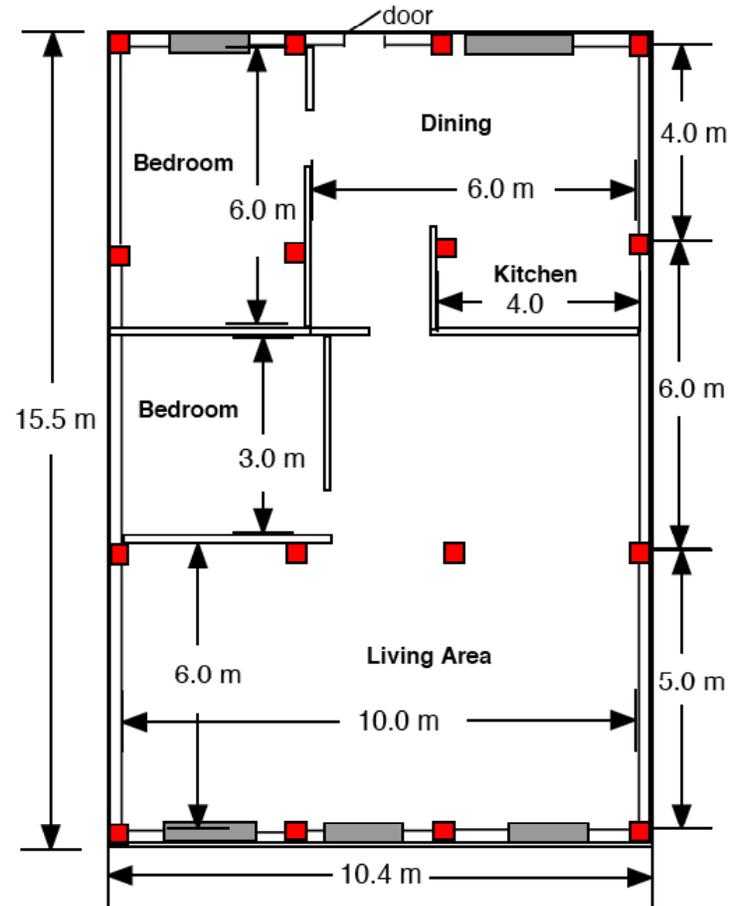


Figure 237. Framed 14-3-b floor plan.

Framed 14-4-a Construction

R/C Framed Construction with CMU Infill Walls; Retail/Residential

Construction Method and Dimensions

Commentary

Loads, in this two story example, are borne by the reinforced concrete columns and beams. Amount of rebar and strength of concrete varies with: height of building; potential earthquake mitigation; economic level of the country in which building is located; quality of materials; local building codes; and adherence to those codes by contractors and inspectors.

Structures are built on concrete platforms, and have web reinforced concrete roofs, and floor/ceilings between stories.

Strength of columns:
305 kg/cm²

Strength of floor/ceilings:
255 kg/cm²

Frame

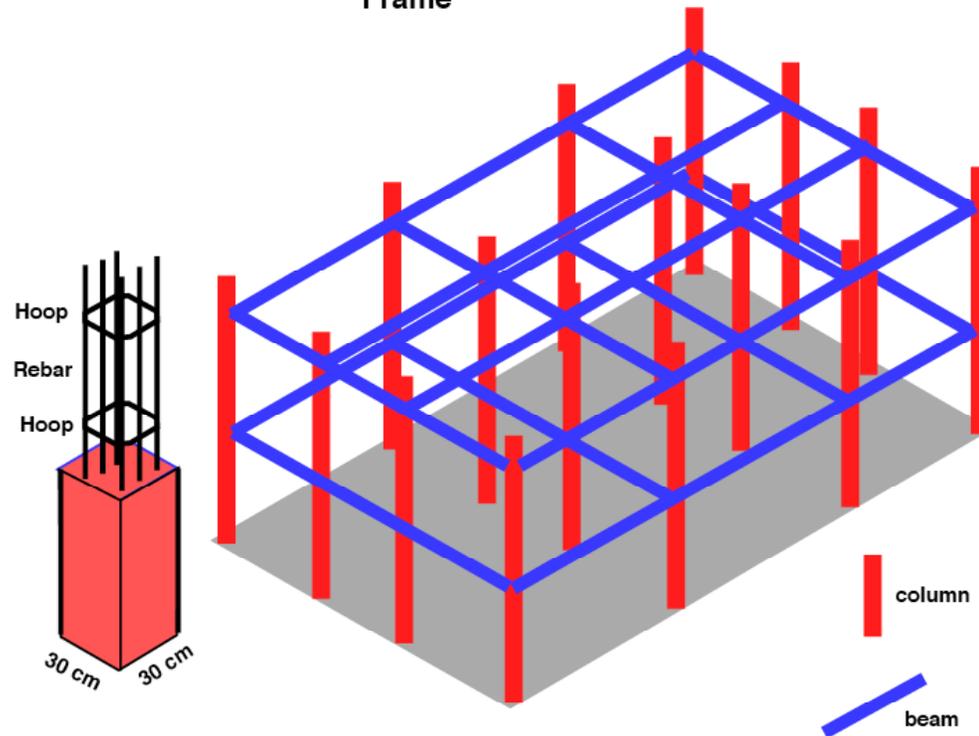


Figure 238. Framed 14-4-a construction.

Framed 14-4-b Construction

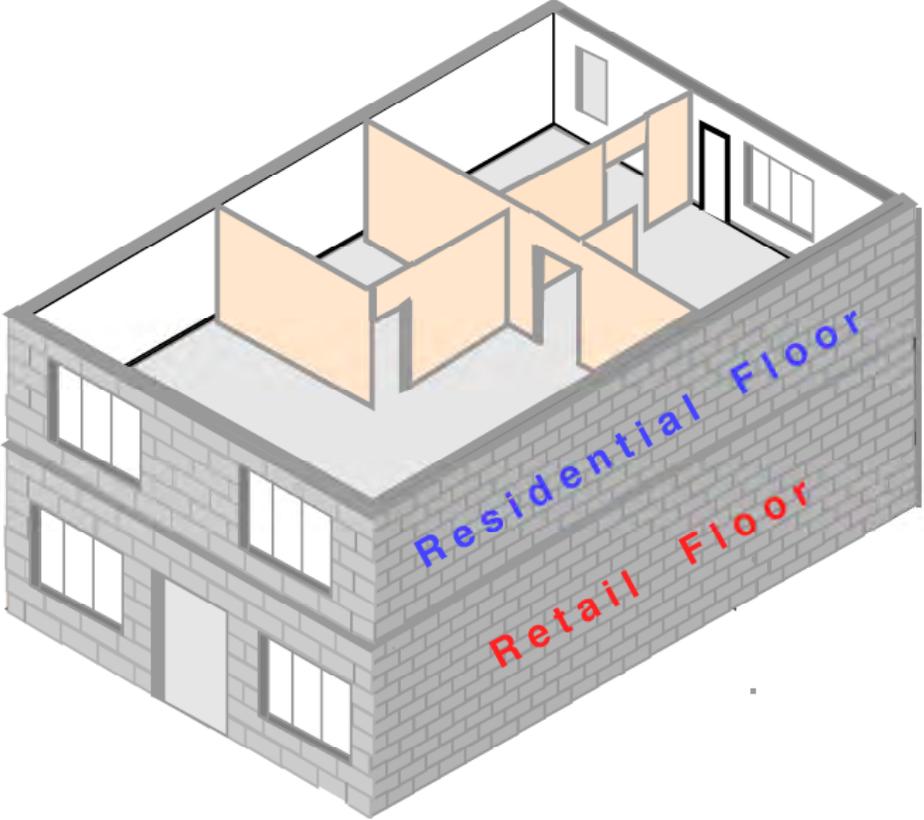
R/C Framed Construction with CMU Infill Walls; Retail/Residential	
Construction Method and Dimensions	
<p>Commentary</p> <p>This isometric (45°) view shows the upper residential floor exposed, venting, and the exposed CMU blocks on both front and side.</p> <p>CMU strength: 152 kg/cm²</p>	<p>Isometric view</p>  <p>The diagram shows a 3D perspective of a building's upper levels. The ground floor is labeled 'Retail Floor' in red text. Above it is the 'Residential Floor', labeled in blue text. The building's exterior walls are made of grey concrete masonry units (CMU). The upper floor is shown with its ceiling and walls removed, revealing the interior structure. The interior walls are also made of CMU blocks, shown in a light orange color. There are several windows and doors visible on the retail floor. The residential floor has a grey floor and a white ceiling. The building is shown from a 45-degree angle, providing a clear view of the construction details.</p>

Figure 239. Framed 14-4-b construction.

Framed 15-1 Place on Building Construction Chart

R/C Framed Construction with Brick Infill Walls; Retail/Office

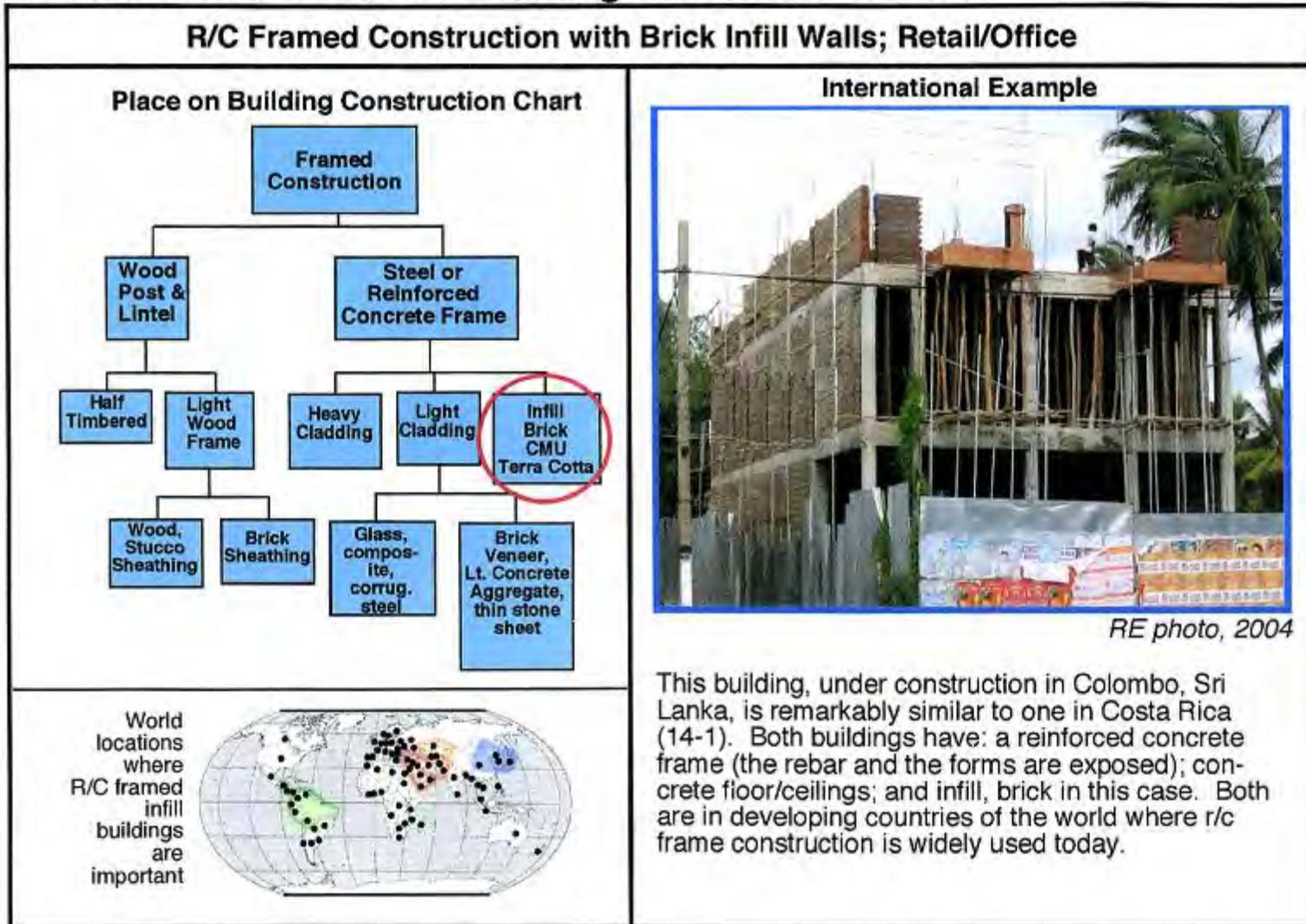


Figure 240. Framed 15-1 place on building construction chart.

Framed 15-2 Elevations

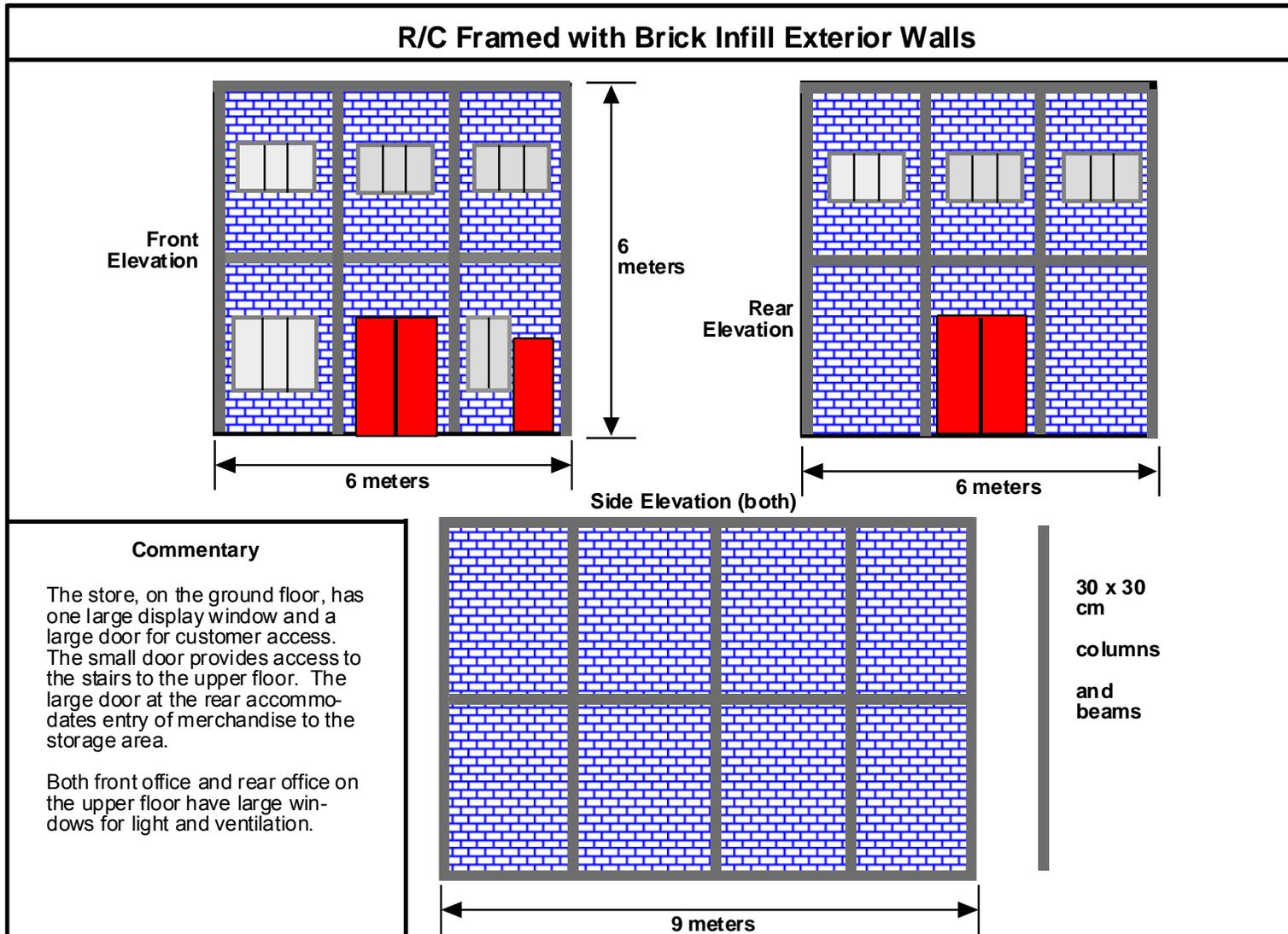
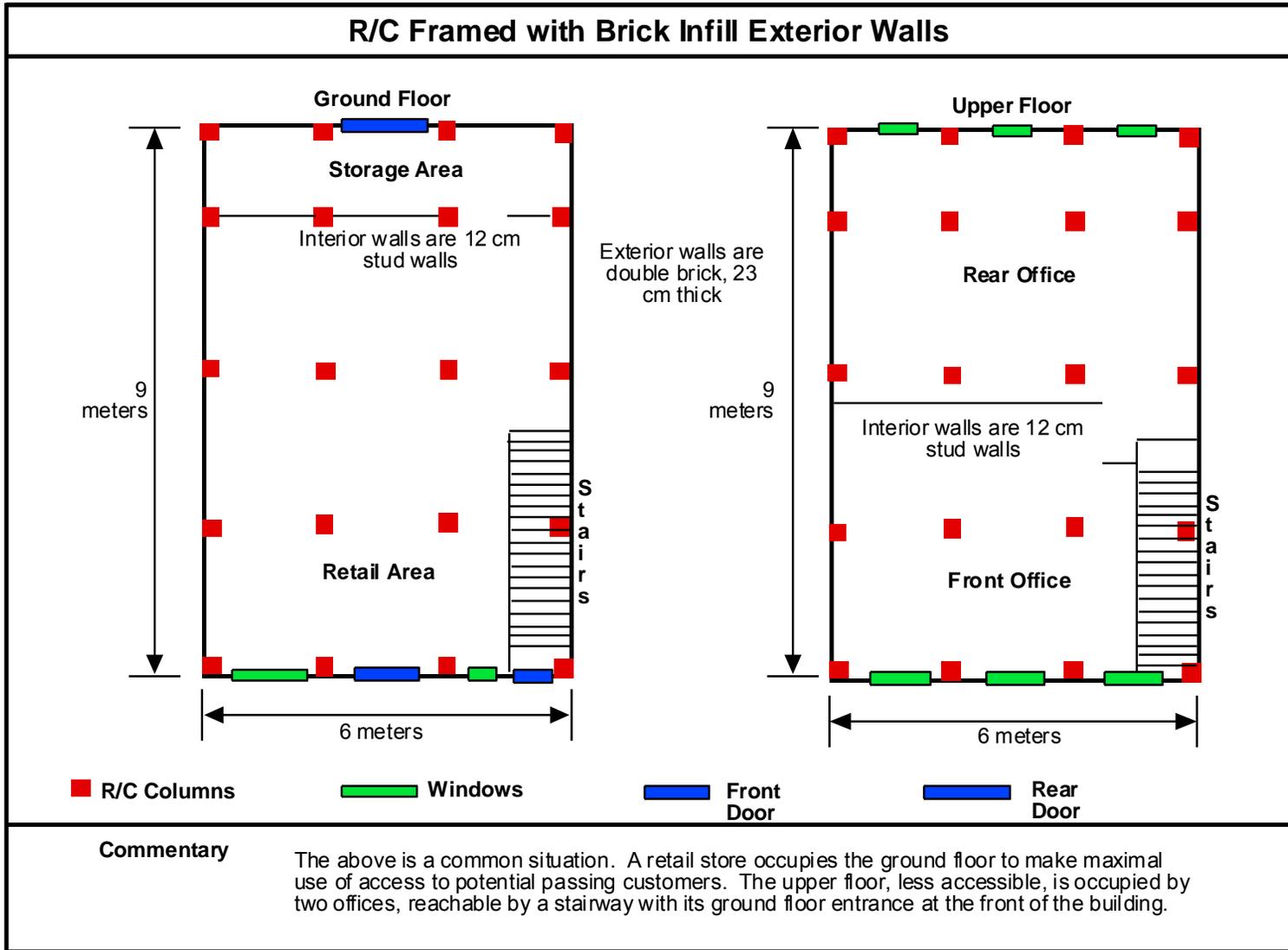


Figure 241. Framed 15-2 elevations.

Framed 15-3-a Floor Plans

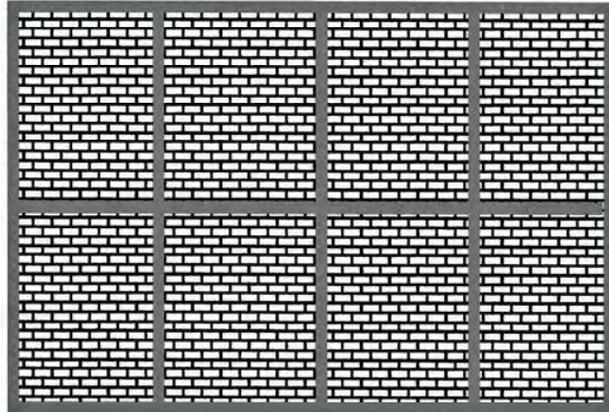


264

Figure 242. Framed 15-3-a floor plans.

Framed 15-4 Construction

R/C Framed with Brick Infill Exterior Walls



9 meters

The standard wall showing r/c columns and beams and brick infill walls.



Commentary

Brick infill can vary greatly in quantity and quality. The upper right example, a street-facing side of a building in Bremen, Germany, uses a refined form of brick infill between R/C mullions. The lower right example, a building in Tel Aviv, Israel, reveals an exceptionally wide (approximately 50 cm) column (with the pattern of the wooden forms still showing). The brick infill is of a size common to the Middle East (23 x 11.5 x 5.7 cm). The wall uses English bond and is apparently three bricks (triple brick) thick. Grouting is irregular indicating that the wall is not structural but serves only to enclose space and provide protection from the elements.

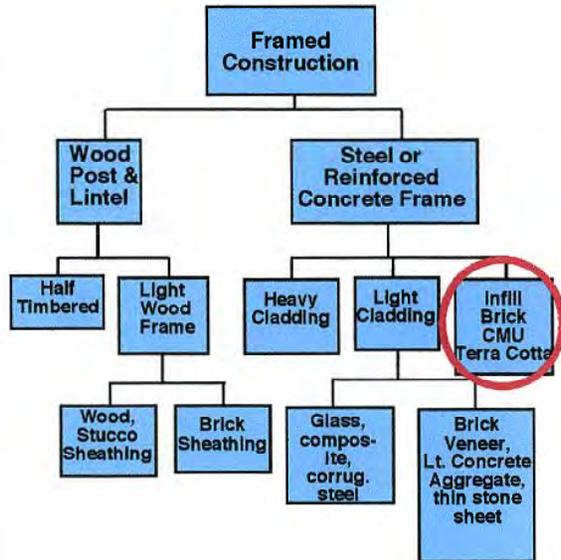


Figure 243. Framed 15-4 construction.

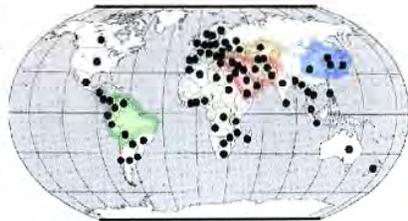
Framed 16-1 Place on Building Construction Chart

R/C Framed Construction Industrial/Storage Building with CMU Infill

Place on Building Construction Chart



World locations where R/C framed infill buildings are important



International Example



RE photo.

This example of CMU infill in an r/c framed industrial/storage building, in Bangkok (2004), demonstrates well the heavy use of concrete in modern construction in a developing country. The form of structure meets modern needs, is relatively inexpensive to construct, and withstands the excessive weathering by the elements found in moist, tropical countries. The ventilation in the upper story is a good indicator of response to climate. The model temple, at the right, manifests the deeply religious aspect of Thailand.

Figure 244. Framed 16-1 place on building construction chart.

Framed 16-2-a Elevation

R/C Framed Construction Industrial/Storage Building (with CMU Infill)

Construction Method and Dimensions

Commentary

This elevation (front of building) displays common elements found in such structures. Loads are borne by the reinforced concrete columns and beams. The columns rest on a mass construction reinforced concrete perimeter foundation that is 1 m tall and 20 cm thick. The infill walls are made with CMU blocks that are also 20 cm thick.

The roof (of corrugated sheet metal in this example) is supported by steel trusses supported by the top beam.

The truck entrance to the large open area within the building is 3.0 x 4 m. The person door, leading to the office, is a standard 1 x 2 m. The single window is also 2 x 1 m.

The window indicates the location of the office.

Front Elevation

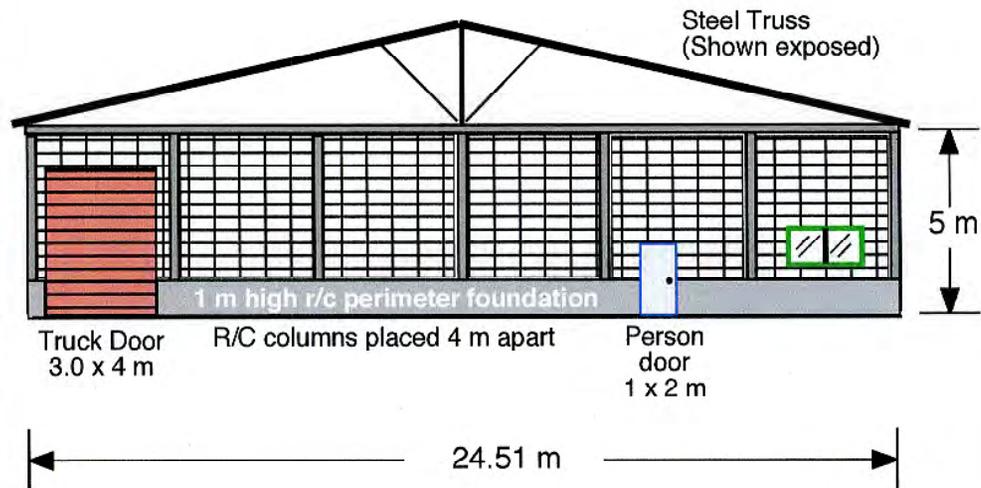
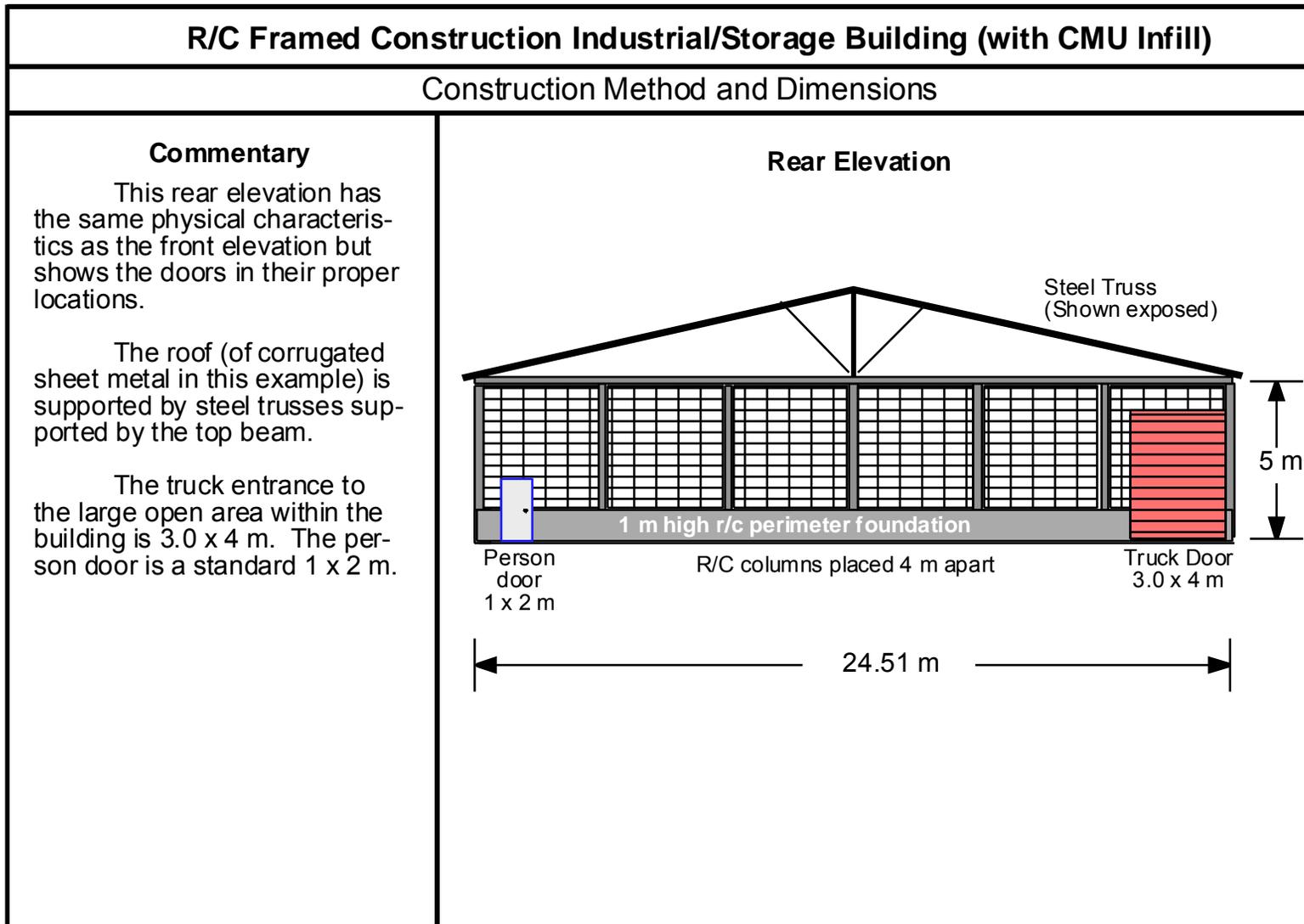


Figure 245. Framed 16-2-a elevation.

Framed 16-2-b Elevation



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Figure 246. Framed 16-2-b elevation.

Framed 16-3-a Floor Plan

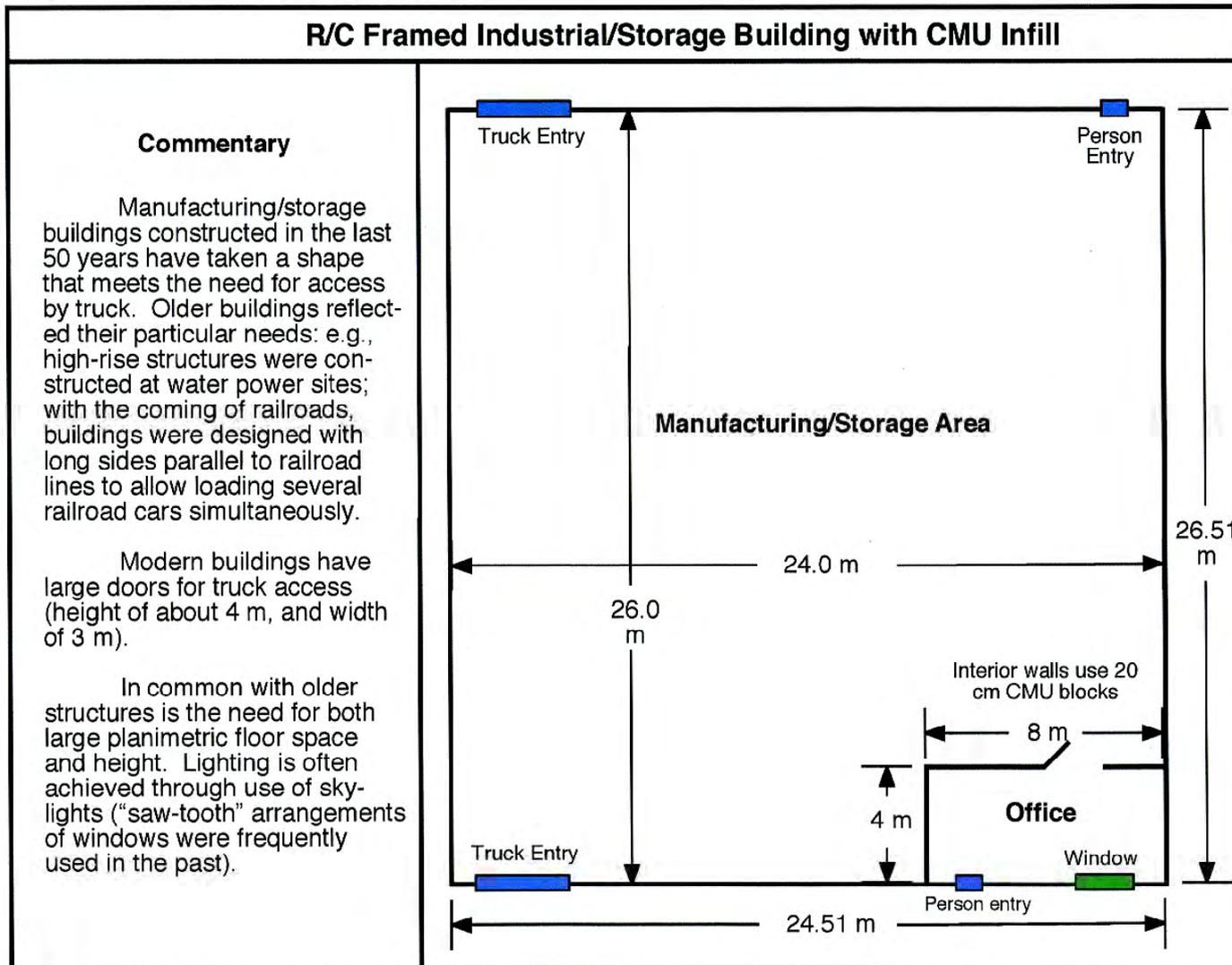


Figure 247. Framed 16-3-a floor plan.

Framed 16-4 Construction

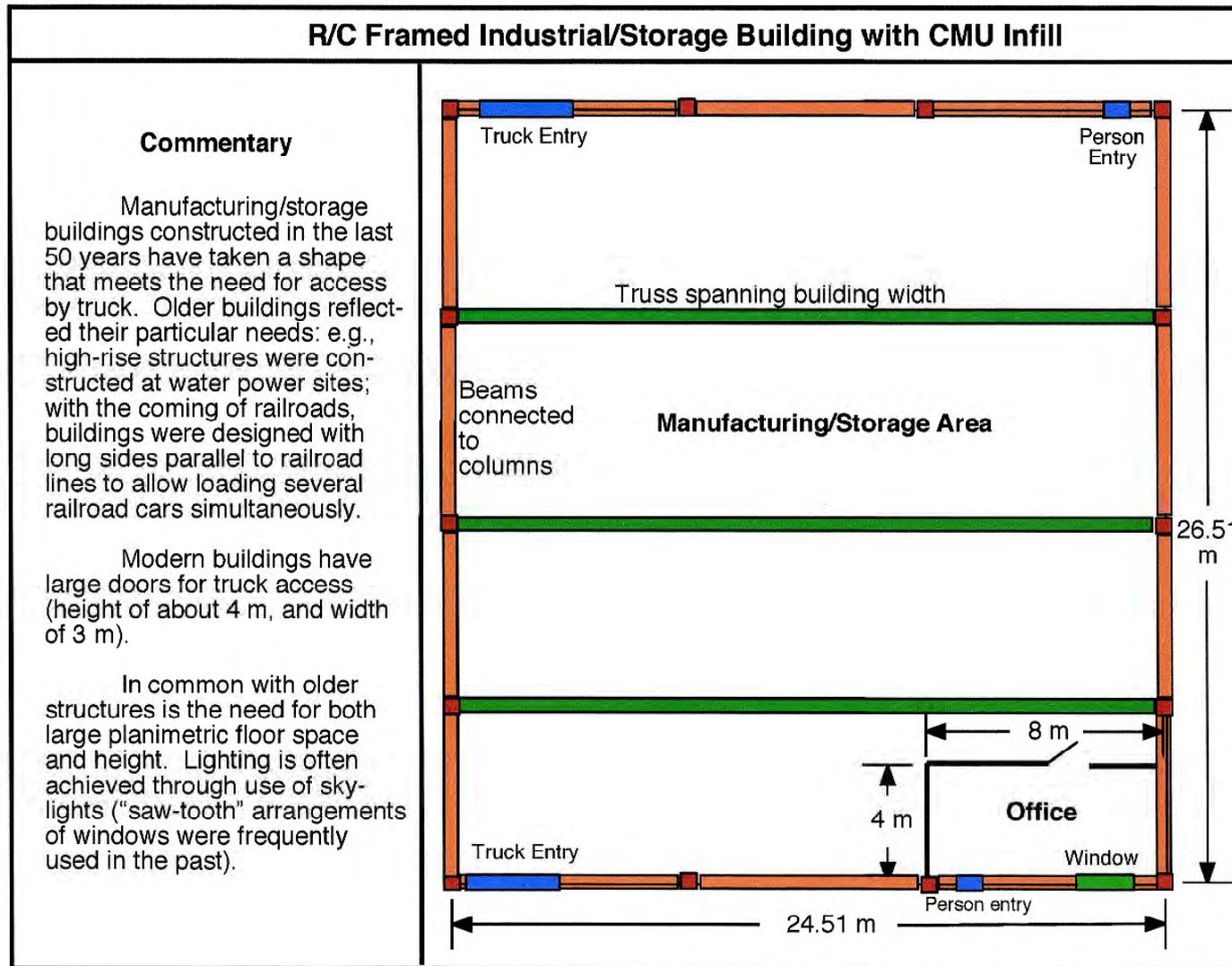
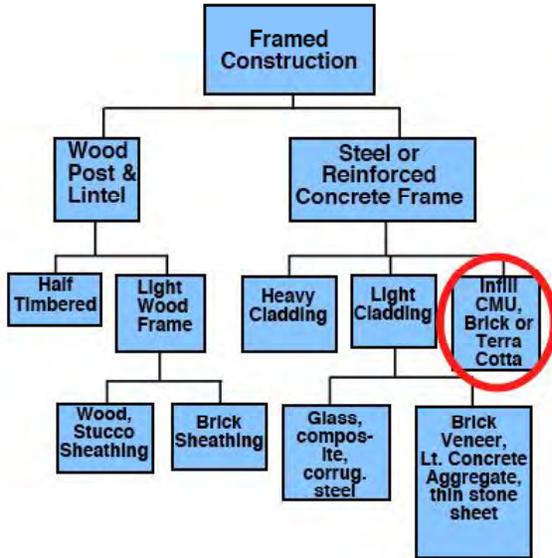


Figure 248. Framed 16-4 construction.

Framed 17-1 Place on Building Construction Chart

R/C Framed Construction Industrial/Storage Building With Terra Cotta Infill

Place on Building Construction Chart



International Example



RE photo.

This industrial/storage building, on St. Croix, is an example of how terra cotta, rather than CMU or brick, can be used as infill.

World locations where R/C framed infill buildings are important

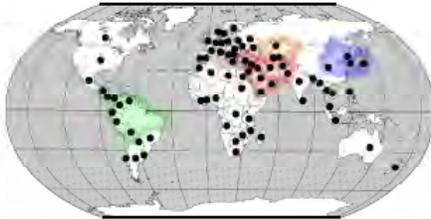


Figure 249. Framed 17-1 place on building construction chart.

Framed 17-2-a Elevation

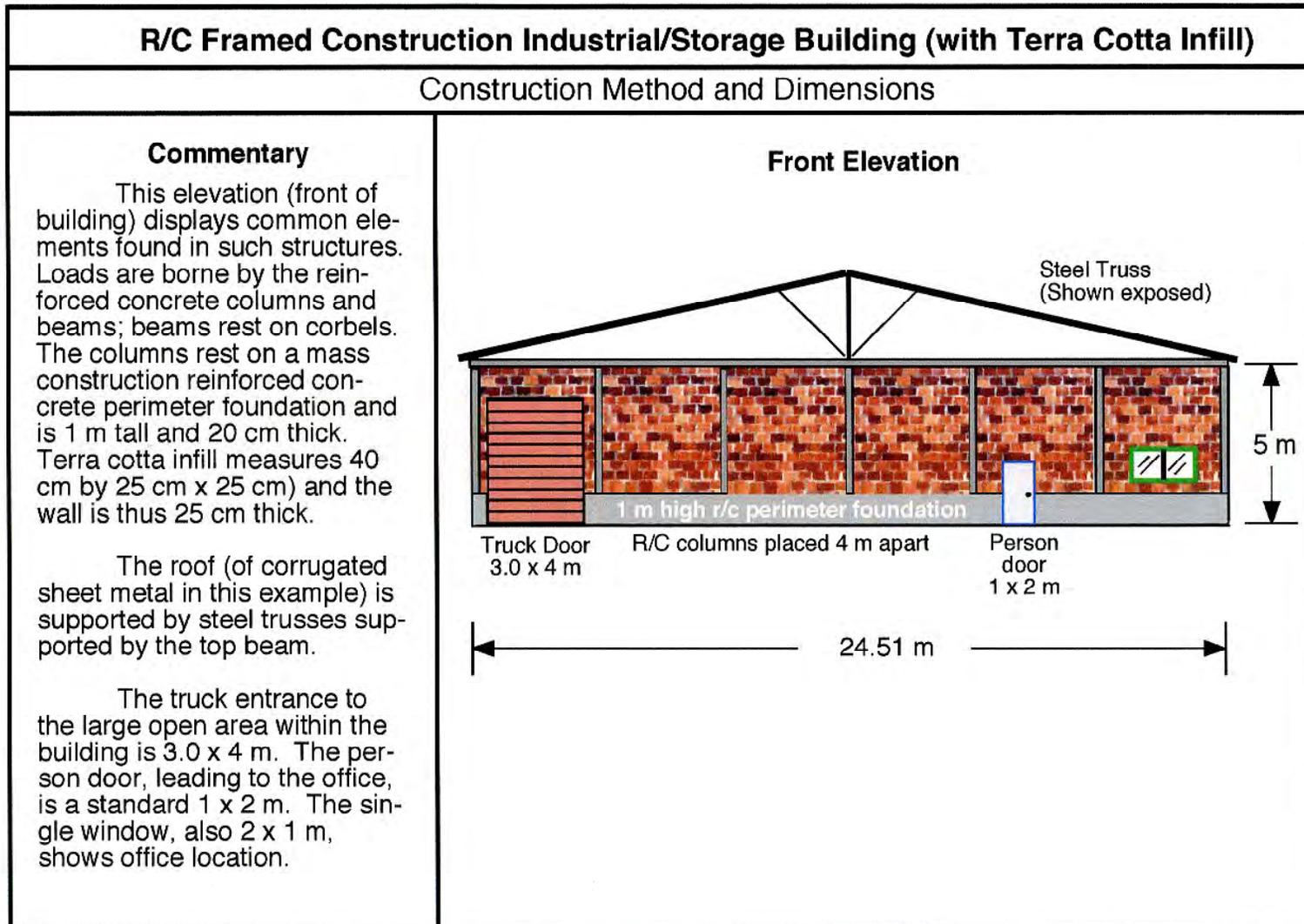


Figure 250. Framed 17-2-a elevation.

Framed 17-2-b Elevation

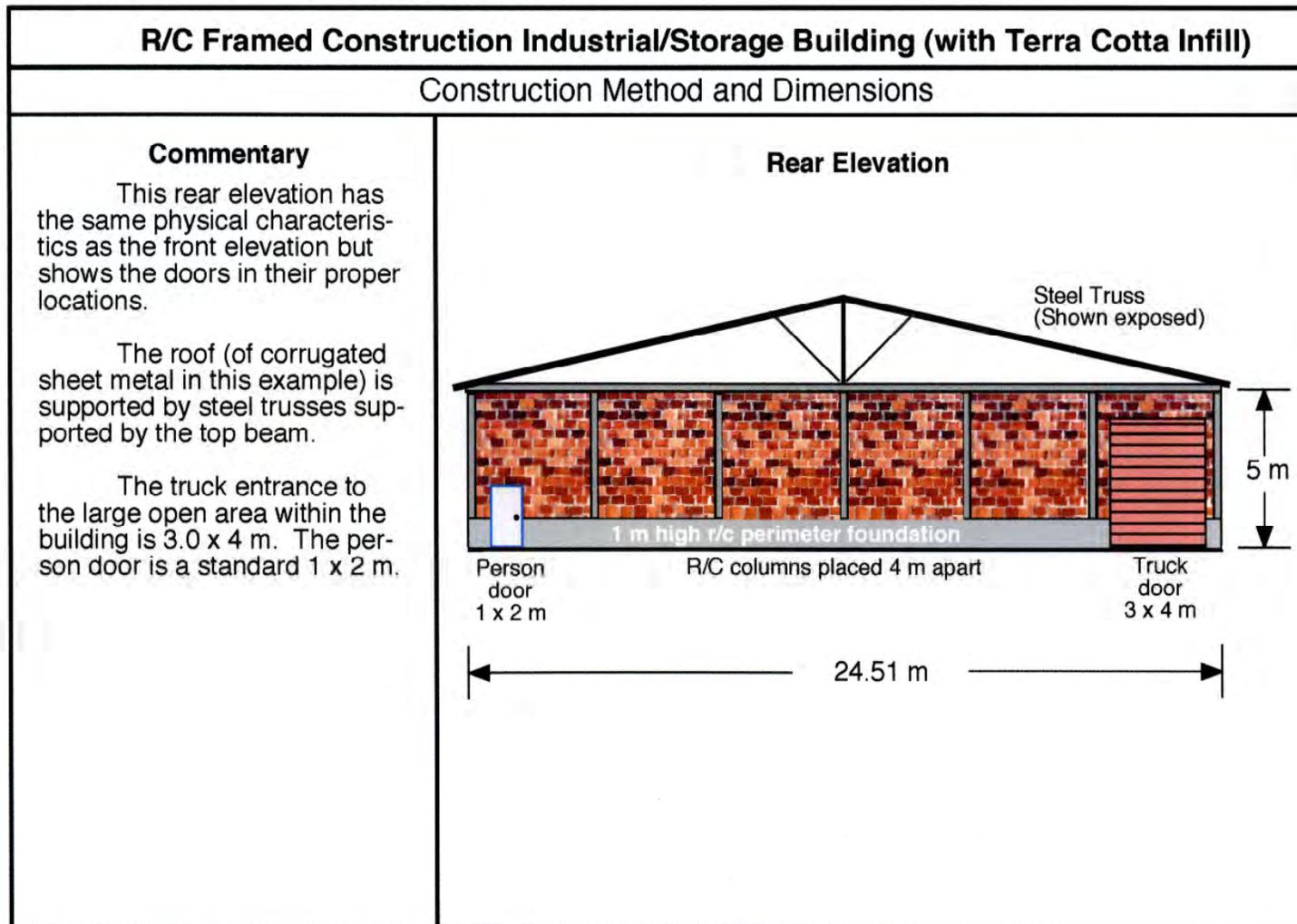


Figure 251. Framed 17-2-b elevation.

Framed 17-3-a Floor Plan

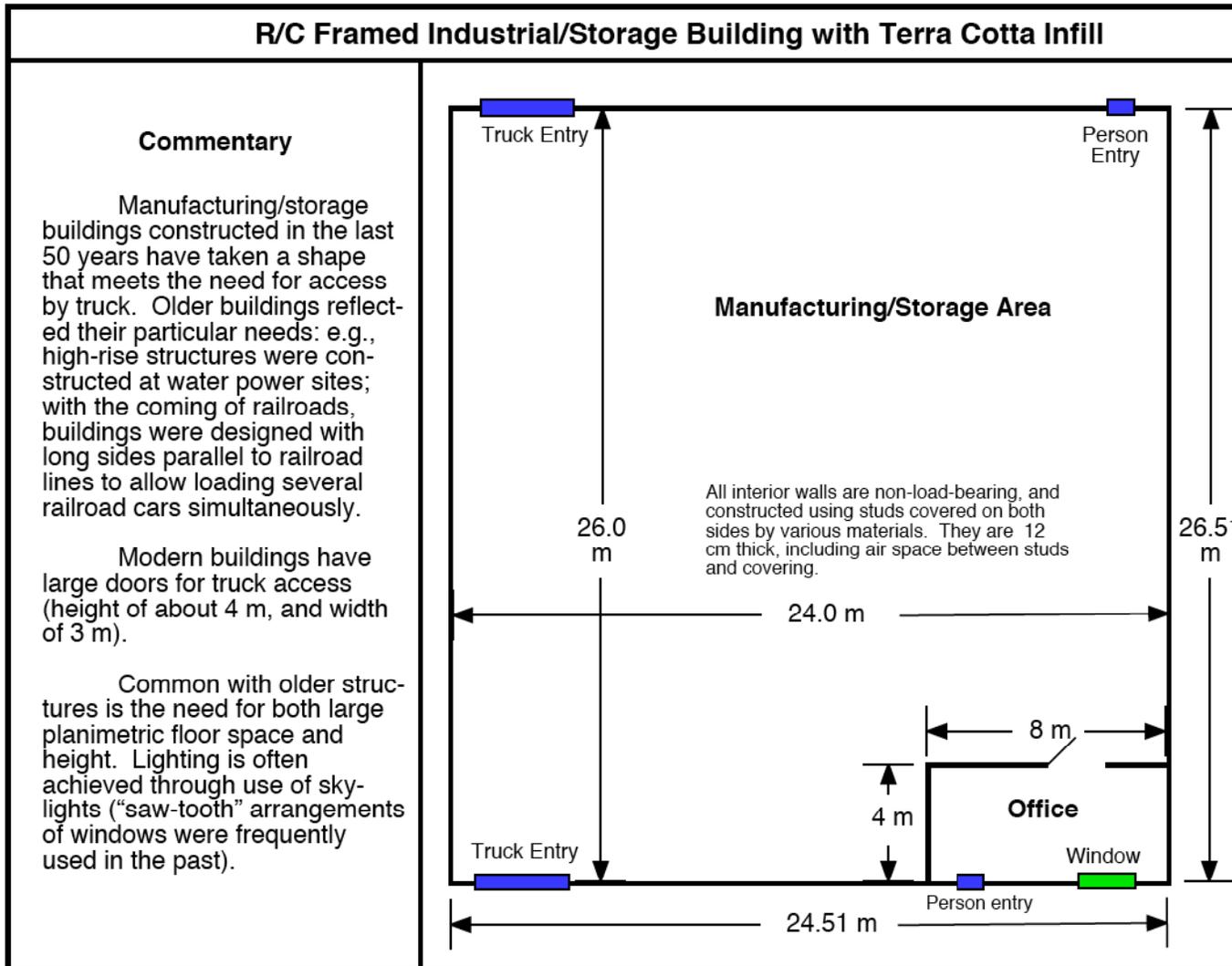


Figure 252. Framed 17-3-a floor plan.

Framed 17-4 Construction

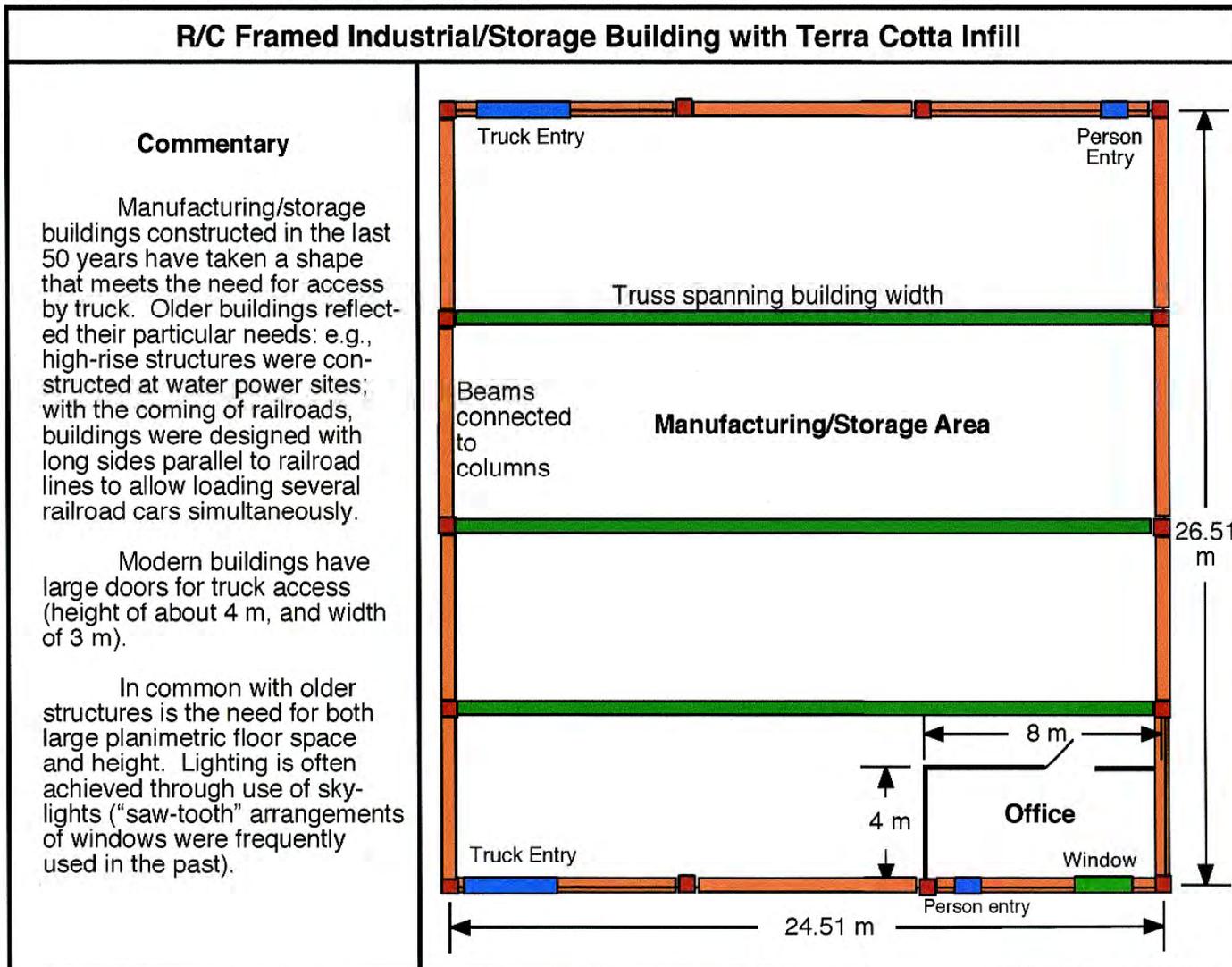
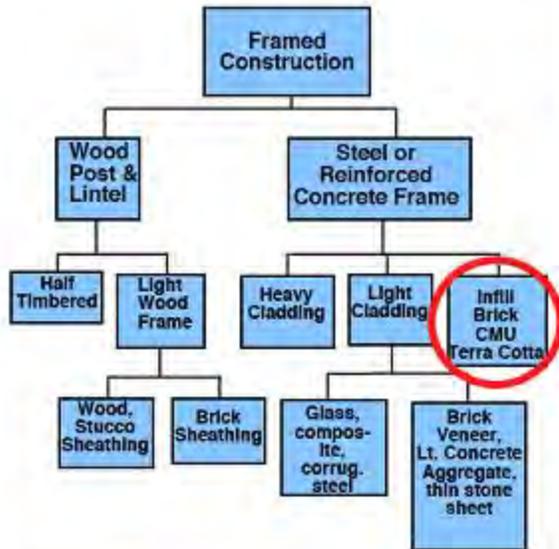


Figure 253. Framed 17-4 construction.

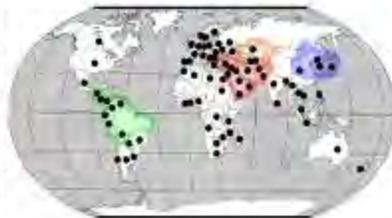
Framed 18-1 Place on Building Construction Chart

R/C Framed Industrial/storage Building with Brick Infill

Place on Building Construction Chart



World locations where R/C framed infill buildings are important



International Example



RE photo

This example of brick infill in an r/c framed industrial/storage building, in Spain, shows how brick, rather than CMU or terra cotta, can be used as infill for a building. This truck dealership has chosen a stylish material as a corporate image enhancement.

Figure 254. Framed 18-1 place on building construction chart.

Framed 18-2-a Elevation

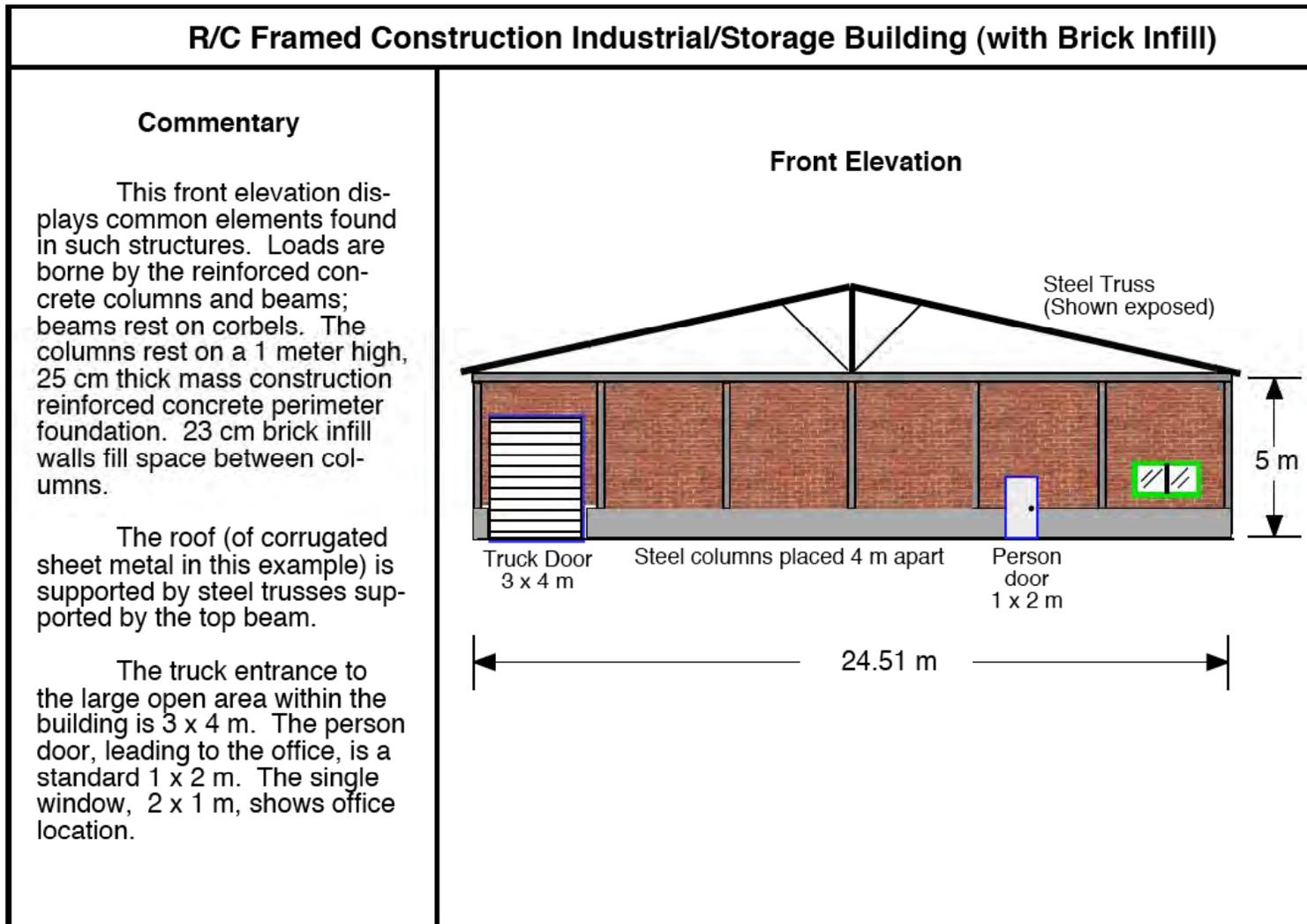
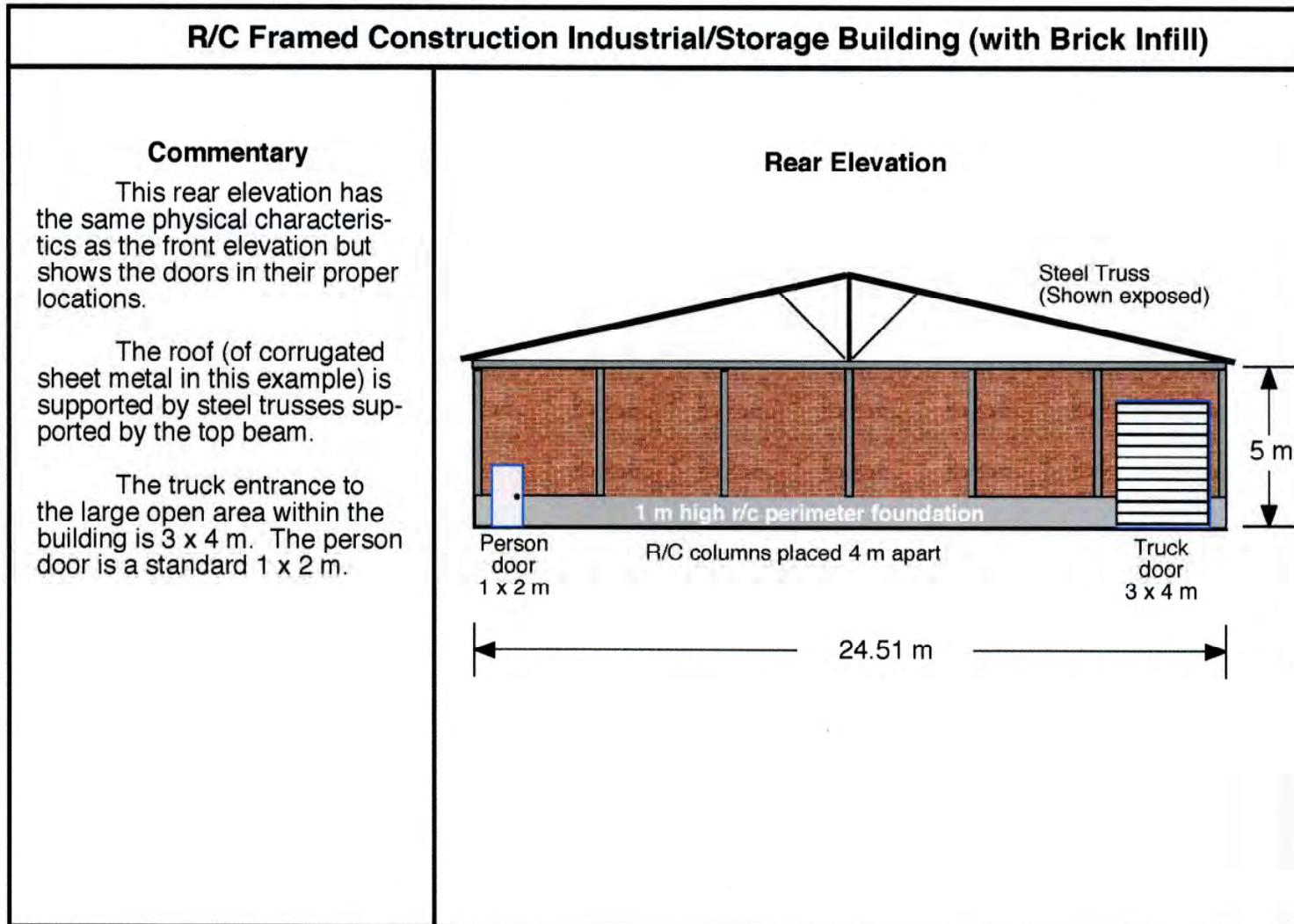


Figure 255. Framed 18-2-a elevation.

Framed 18-2-b Elevation



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Figure 256. Framed 18-2-b elevation.

Framed 18-3-a Floor Plan

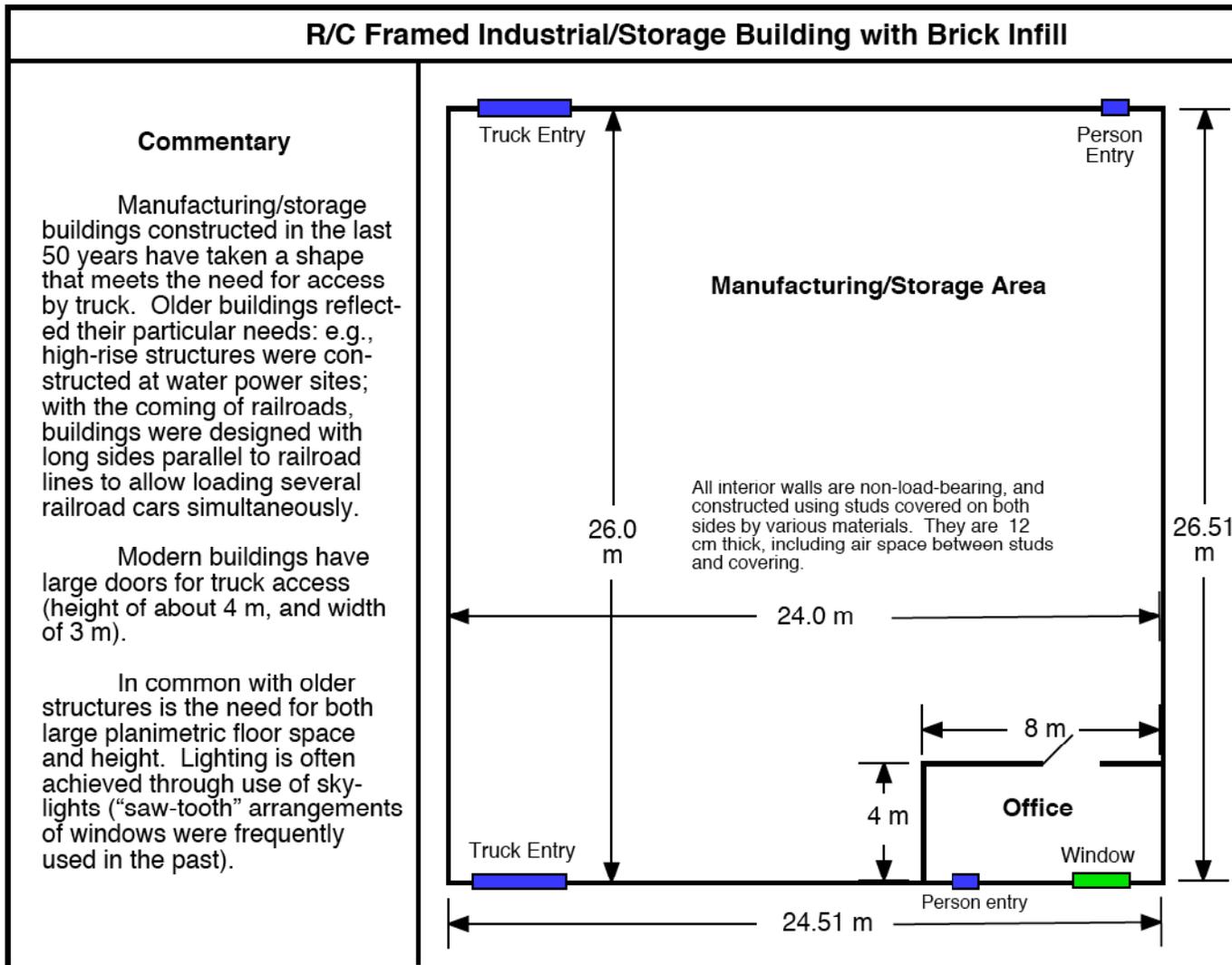


Figure 257. Framed 18-3-a floor plan.

Framed 18-4 Construction

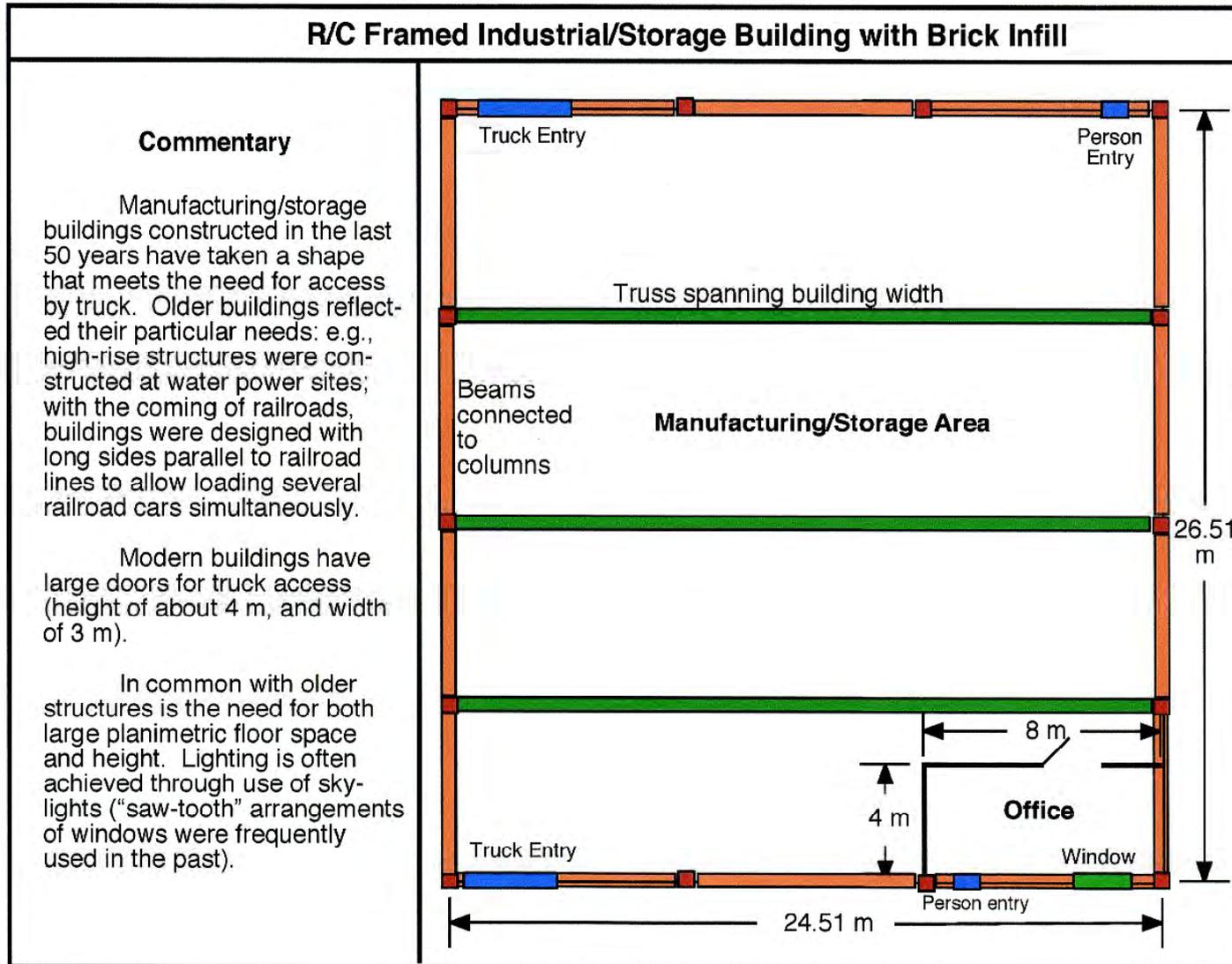
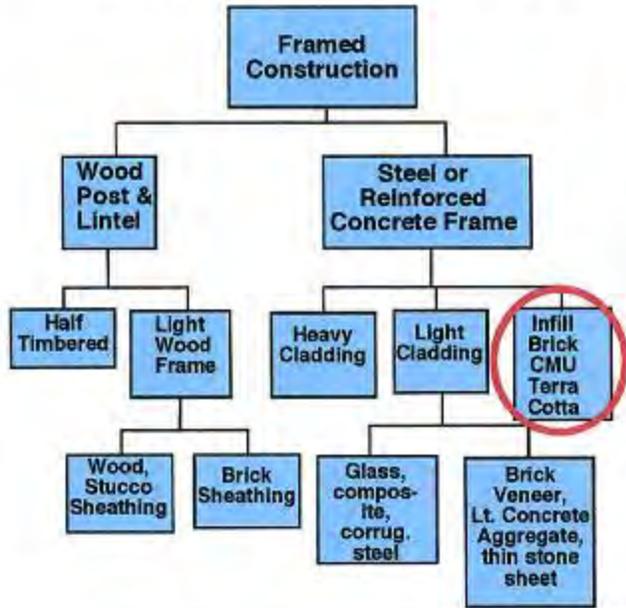


Figure 258. Framed 18-4 construction.

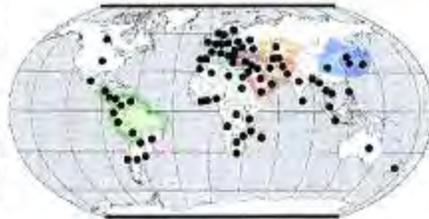
Framed 19-1 Place on Building Construction Chart

R/C Framed Construction School with Brick Veneer over Infill Walls

Place on Building Construction Chart



World locations where R/C framed infill buildings are important



International Example



RE photo.

Framed buildings are especially suited to such institutional uses as schools as the long spans of the beams allow the enclosure of large spaces, e.g., classrooms. Infill material between frame members is covered with a brick veneer. This example is in Uppsala, Sweden (1994).

Figure 259. Framed 19-1 place on building construction chart.

Framed 19-2 Elevation

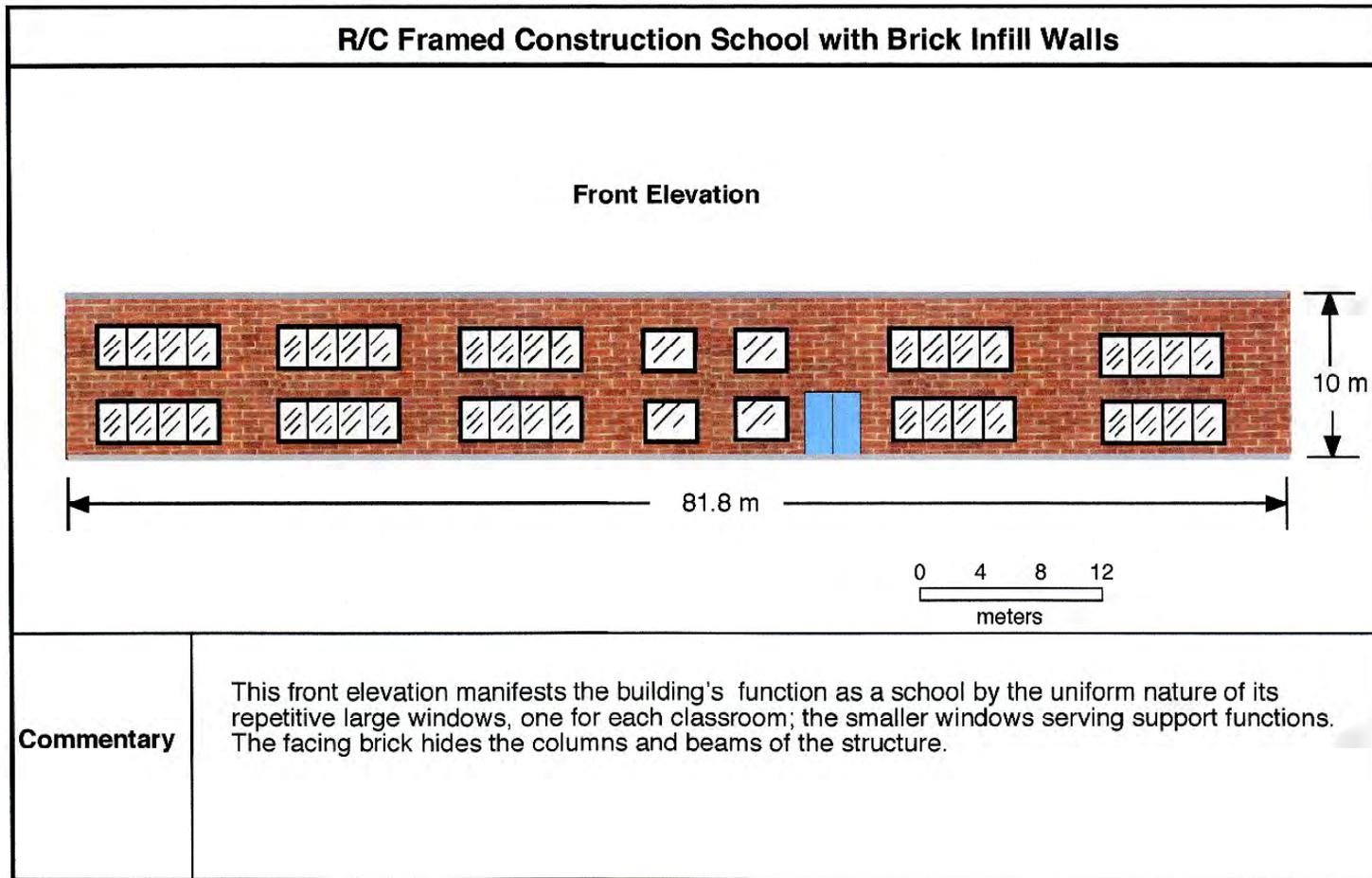


Figure 260. Framed 19-2 elevation.

Framed 19-3-a Floor Plan

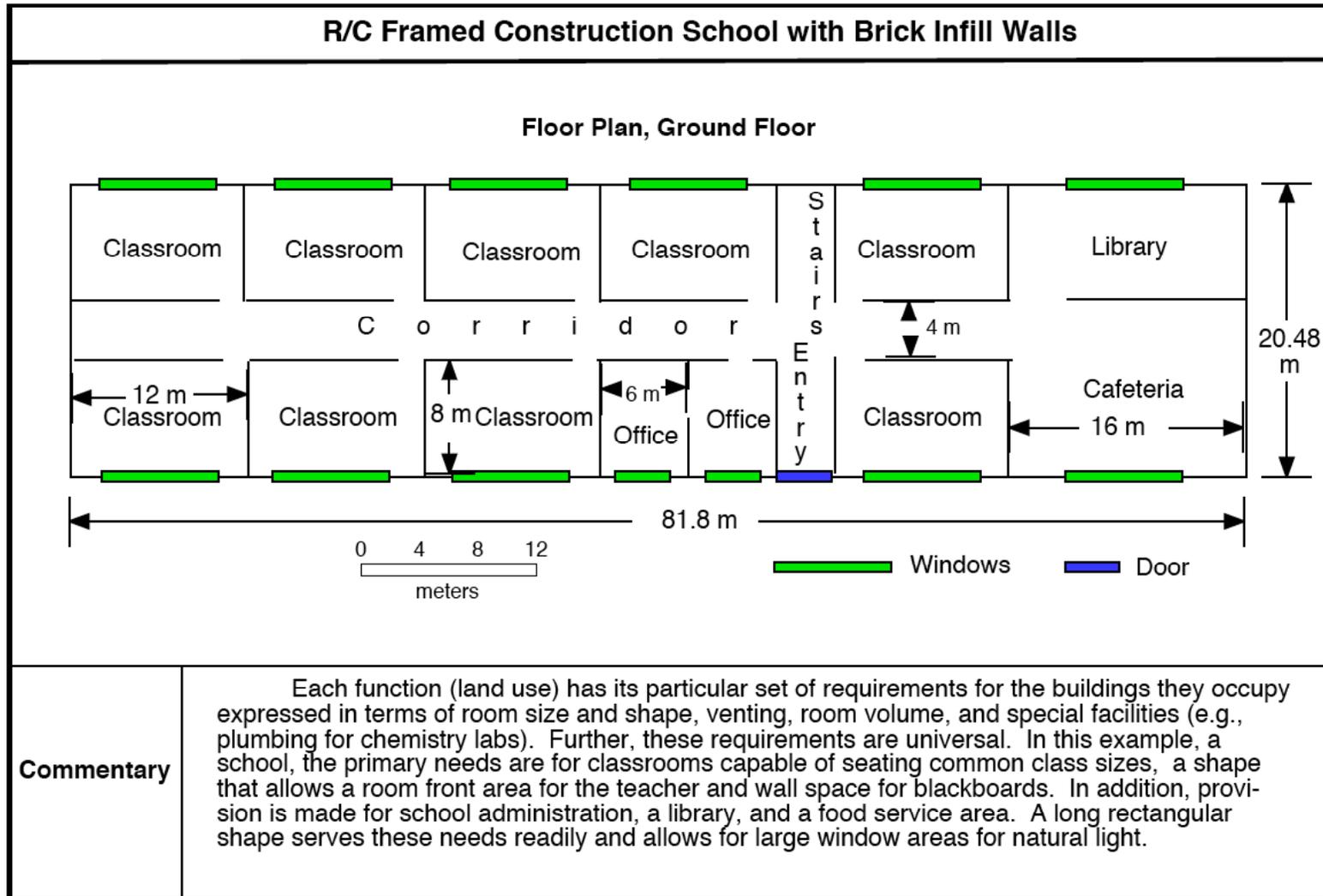


Figure 261. Framed 19-3-a floor plan.

Framed 19-3-b Floor Plan

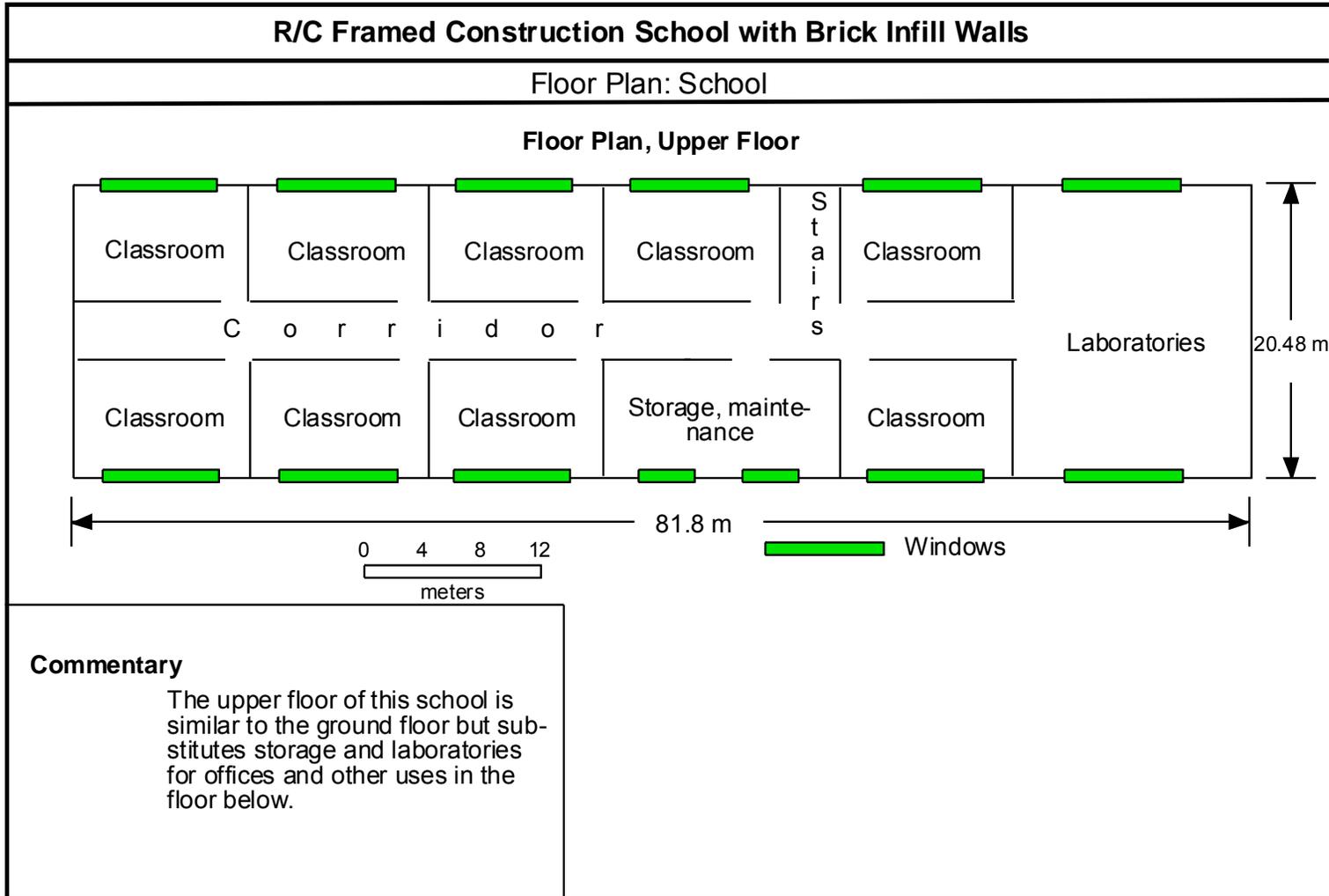
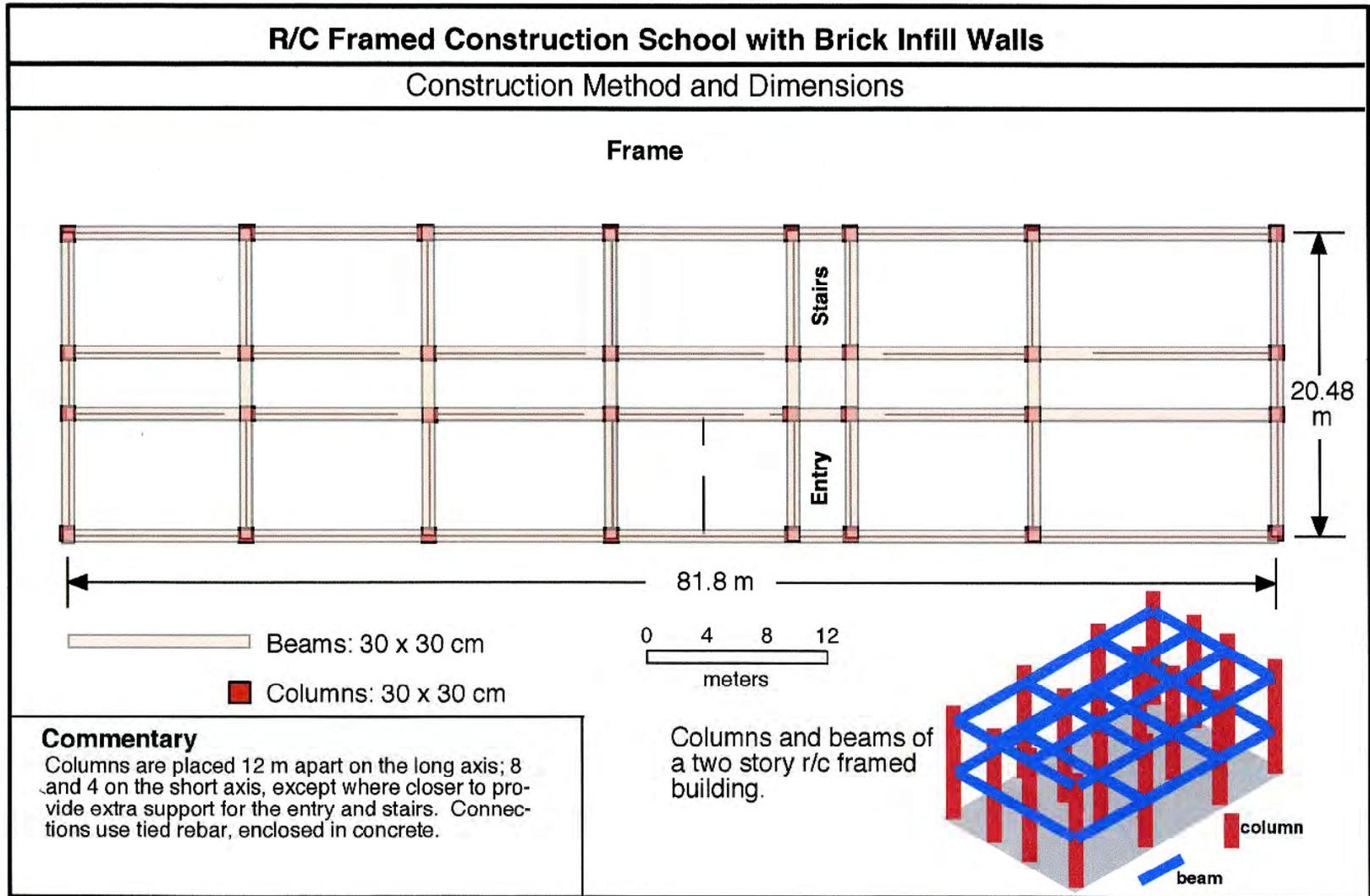


Figure 262. Framed 19-3-b floor plan.

Framed 19-4 Construction



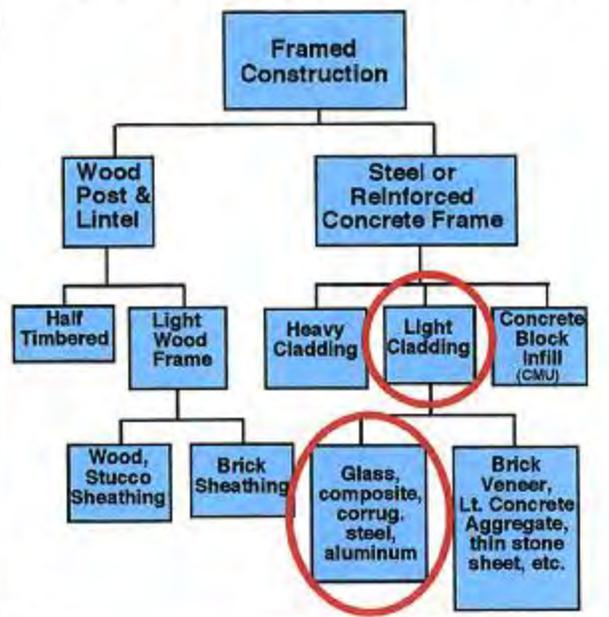
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Figure 263. Framed 19-4 construction.

Framed 20-1 Place on Building Construction Chart

Steel-framed, Light cladding Industrial/Storage Building

Place on Building Construction Chart



International Examples



German building with composite corrugated outer cover. RE Photo.



Simple steel framed, corrugated aluminum partially covered building on the island of Yap. RE Photo.



Figure 264. Framed 20-1 place on building construction chart.

Framed 20-2 Elevation

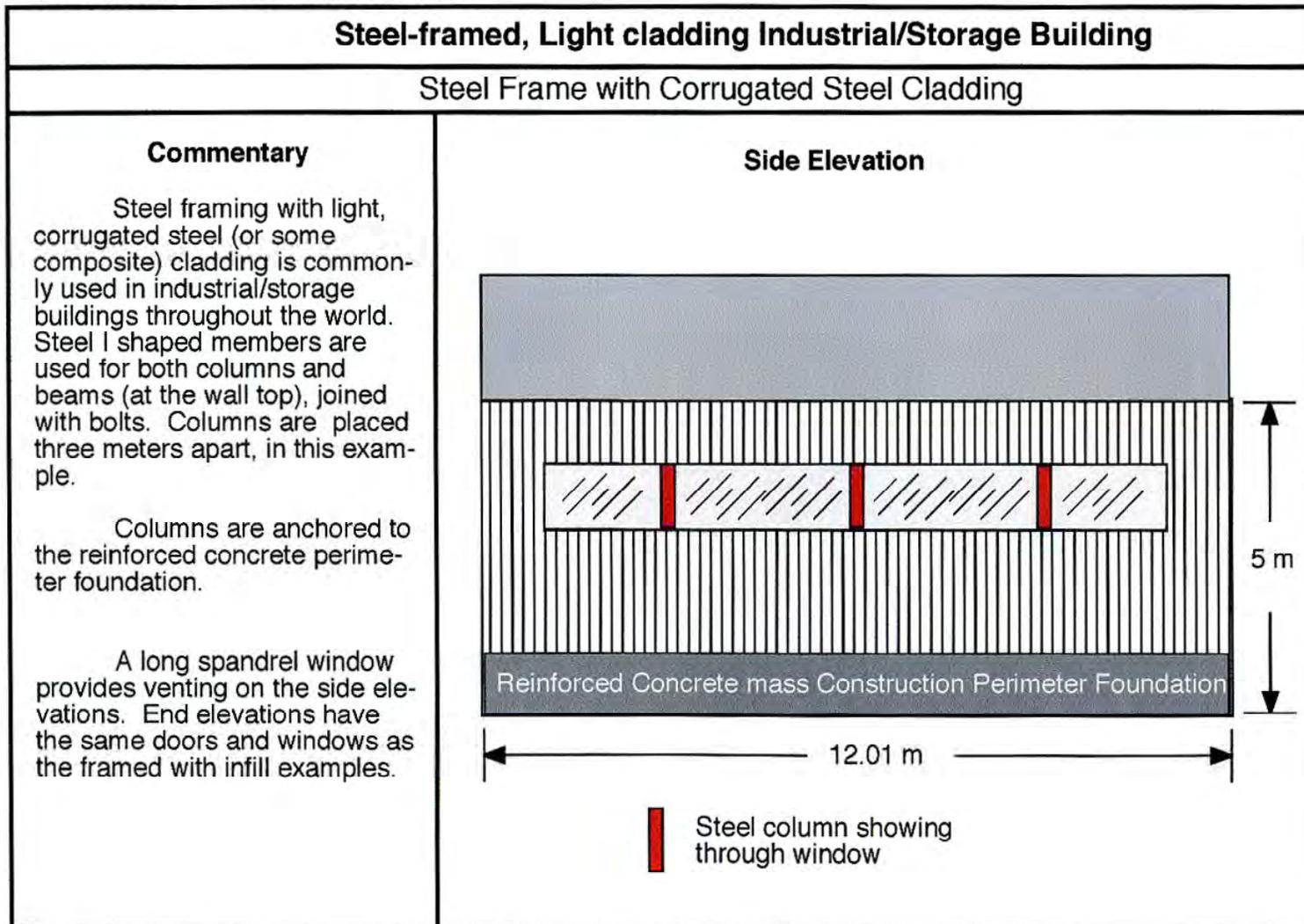


Figure 265. Framed 20-2 elevation.

Framed 20-3-a Floor Plan

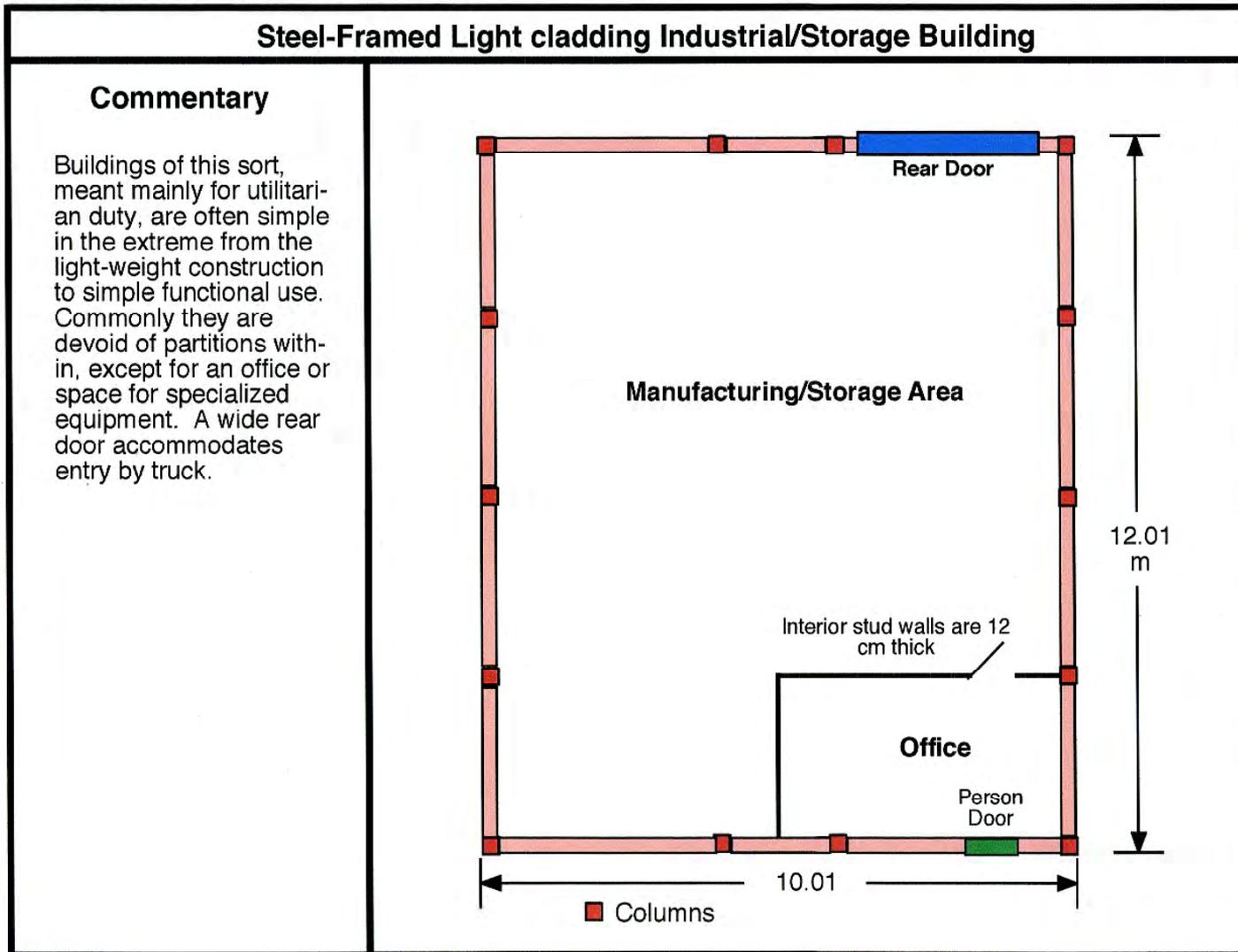
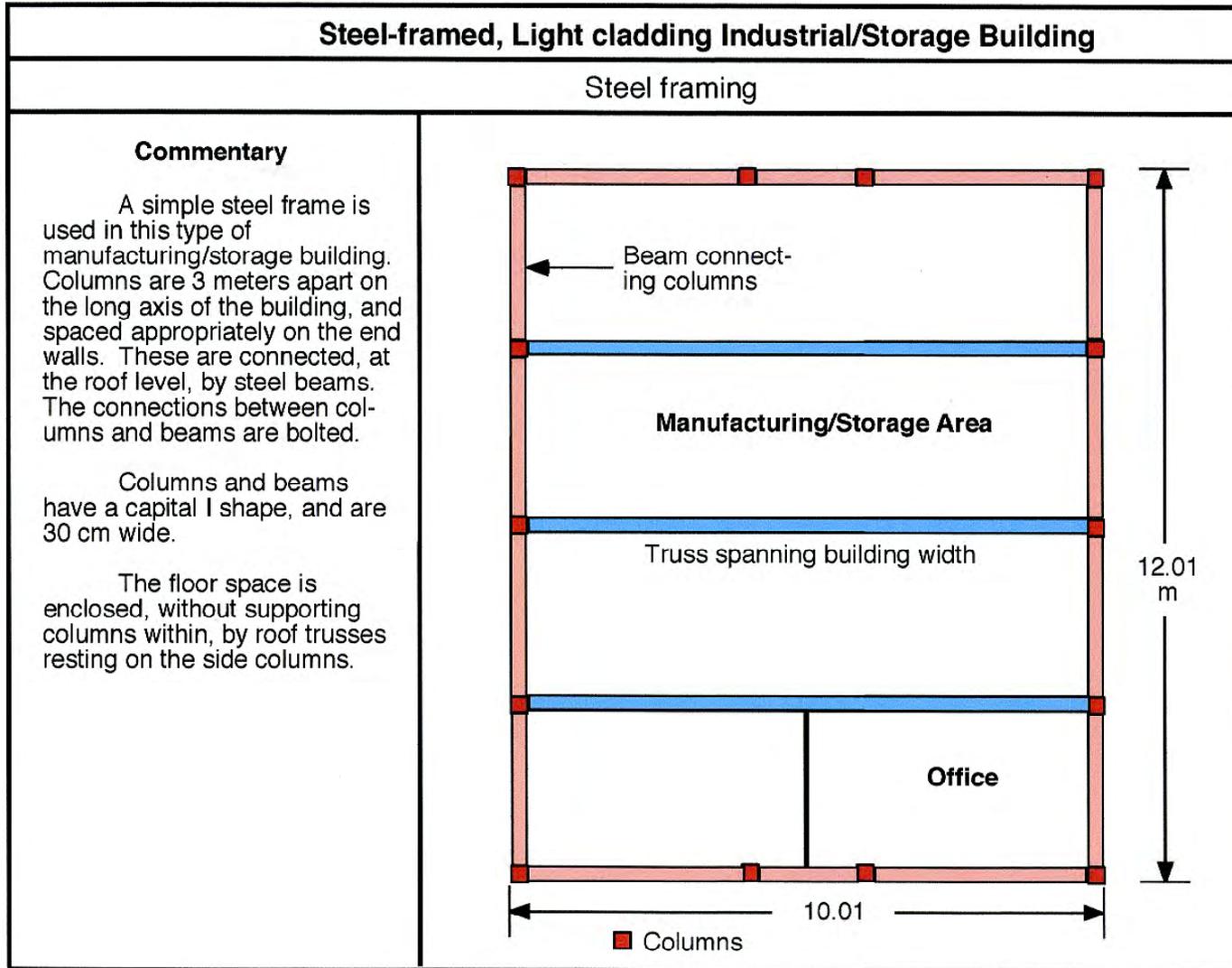


Figure 266. Framed 20-3-a floor plan.

Framed 20-4 Construction



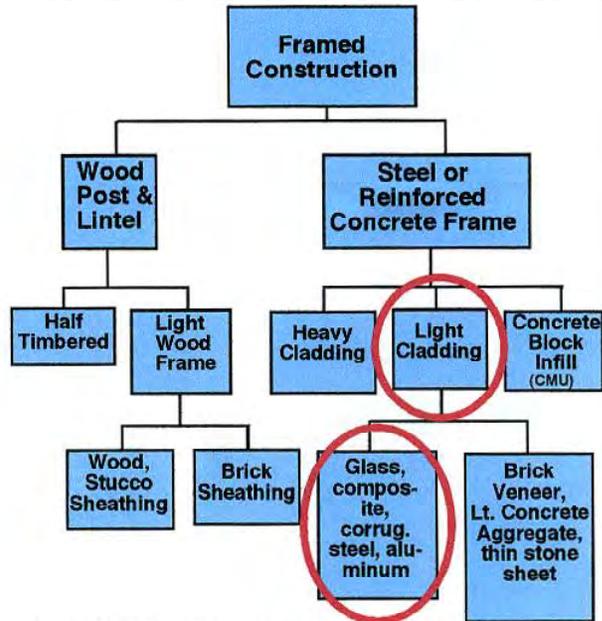
289

Figure 267. Framed 20-4 construction.

Framed 21-1 Place on Building Construction Chart

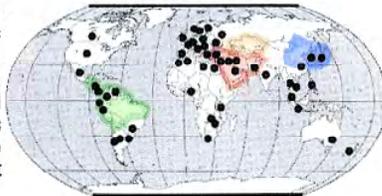
Corrugated Steel Panels on a Steel Framed Industrial Building (Multiple unit)

Place on Building Construction Chart



Light cladding here refers to a thin corrugated metal skin placed on a steel frame.

World locations where R/C-Steel Light clad buildings are important



International Example



RE photo.

Steel framed industrial/storage building, in England, placed on a reinforced concrete perimeter foundation. Outer wall uses corrugated steel. Roof panels are corrugated composite material. Skylights are common in this type of structure.

Figure 268. Framed 21-1 place on building construction chart.

Framed 21-2 Elevation

Corrugated Steel Panels on a Steel-Framed Industrial/Storage Building (multiple unit)

Commentary

The end view elevation of this twin building shows the very limited entry: the truck door and the person door. Ventilation is limited, but little needed given the industrial or storage function of the building. Natural interior lighting is provided by the skylights.

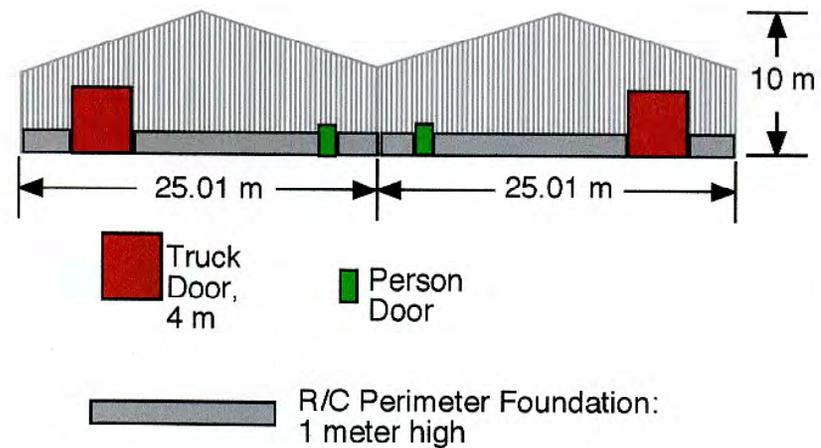


Figure 269. Framed 21-2 elevation.

Framed 21-3-a Floor Plan

Corrugated Steel Panels on a Steel-Framed Industrial/Storage Building (multiple unit)

Commentary

Buildings of this type, very common throughout the world, are designed to enclose large areas of space with few, or no, internal columns to impede the manufacturing or storage function. In this example, twin buildings have been constructed side by side, a common mode. The method has the advantage of obviating the need for extraordinarily long spans or a very high roof, if the building were but a single structure.

Floor Plan, Pair of Industrial/Storage Buildings

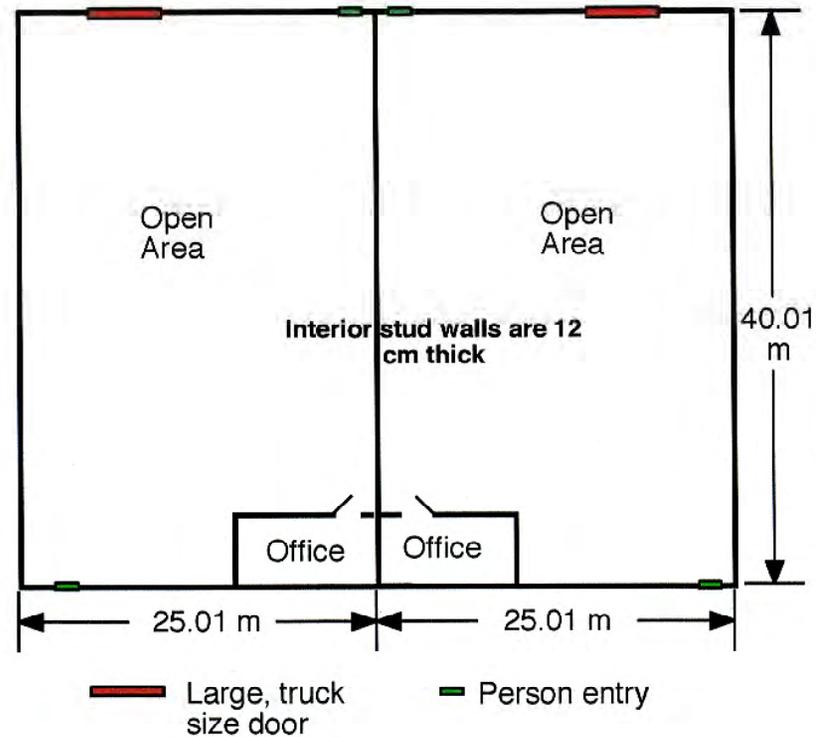


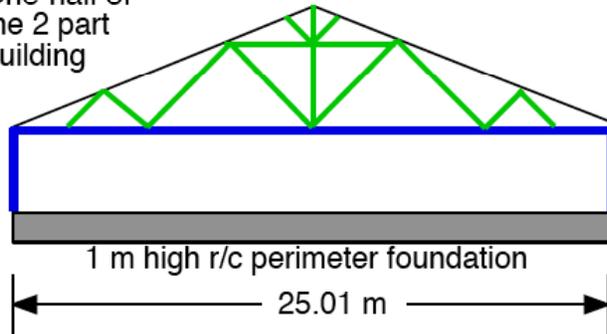
Figure 270. Framed 21-3-a floor plan.

Framed 21-4 Construction

Corrugated Steel Panels on a Steel-Framed Industrial/Storage Building (multiple unit)

Structural Details

One-half of the 2 part building



Steel (I beams) columns and beams 15 cm square

Steel truss members 10 cm square

Commentary

The light weight of walls and roof requires only minimal size supporting steel beam columns and beams. Use of a truss, with its cross bracing, also requires only light steel structural members. Columns and beams are spaced 10 meters apart, except where the two halves of the building meet. Support columns rest on and are attached to the r/c perimeter foundation.

Steel Structural Members to Support Walls and Roof

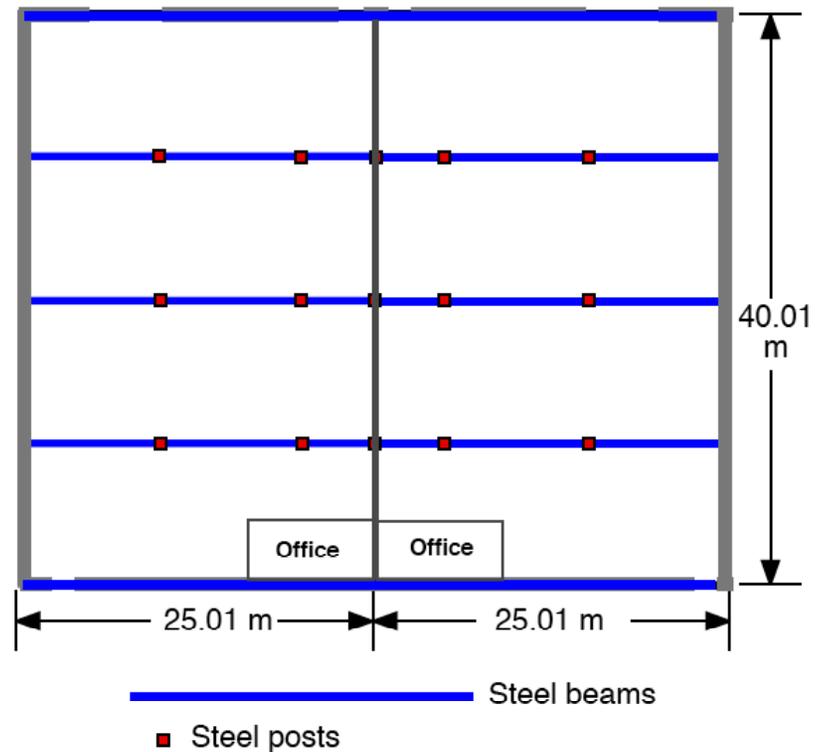


Figure 271. Framed 21-4 construction.

13. Urban Terrain Zones

The UTZ inventory system plays an integral supporting role to the UTBTs depicted in this report. While the building type catalog provides details on the characteristics of each structure type, the UTZs give them a locational home within a city. Indeed, the UTZ system—applicable worldwide—was designed for the express purpose of providing the urban operations planner with information on the nature of buildings to be anticipated in various parts (zones) of the urban environment.

To delineate a UTZ, the presence of various building types and settings is first observed, either from synoptic aerial or satellite views, and confirmed with ground truth if possible. Areas of homogeneous building types then become the UTZs. Then, lines are drawn to bound these homogeneous areas of like buildings; the appropriate UTZ class number is then assigned. For each UTZ plate, the building characteristics are as follows:

1. **Building Function and Density** (as in the title of each UTZ). The function outlines common land-use classes, i.e., houses, apartments, commercial, industrial, and institutions. The density outlines buildings that are attached (or abutted); detached but closely spaced; or detached and widely spaced.
2. **Building Separation**. Statement and measurement of the amount of space separating buildings, either attached, closely spaced (less than 13 m), or widely spaced (more than 13 m).

3. Building Setting. Where the UTZ is located within the city, e.g., city core, new residential development at the edge of the city, or along railroad lines.
4. Building Construction Type. The general type of construction is listed, e.g., brick or R/C framed with infill walls.
5. Range of Building Heights. The height is given in stories, ranging from houses 2 to 3 stories, to city core areas with buildings from 5 to 50+ stories.
6. Age. The period when most of the buildings in a UTZ were constructed, e.g., post–World War II for a modern suburban development.

The UTZ system is essentially a method to inventory the morphology of an entire city (covering the full area of the corporate city and its adjacent contiguously built-up area that frequently includes other corporate units and built-up unincorporated areas). Taking such an inventory produces a map on which boundaries demarcating the zones have been drawn (see figures 274 and 275 for examples). For a variety of users—ranging from urban operations to weapons and munitions testers, to combat development, and to the modeling and simulation community—UTZ maps give critical information on the quantity and spatial distribution of the various building construction types. Analysis of the map product quickly reveals, for example, the relative number of framed high-rise buildings vs. low-rise brick houses.

Urban operations can take advantage of the naturally occurring spatial clustering of similar building types in homogeneous zones, or sectors, within a city. This is the product of a universal response to economic laws and principles, such as the A1 UTZ with its attached buildings occupying much of their land parcels to make maximal use of expensive land, made so by being located at significant junction points, such as road intersections or river confluences. In another example, industrial land uses and their associated building types are found along rail lines or at a break-of-bulk point where rails meet navigable water. Urban zoning, coming along later, simply codifies these natural occurring clusters of like land uses.

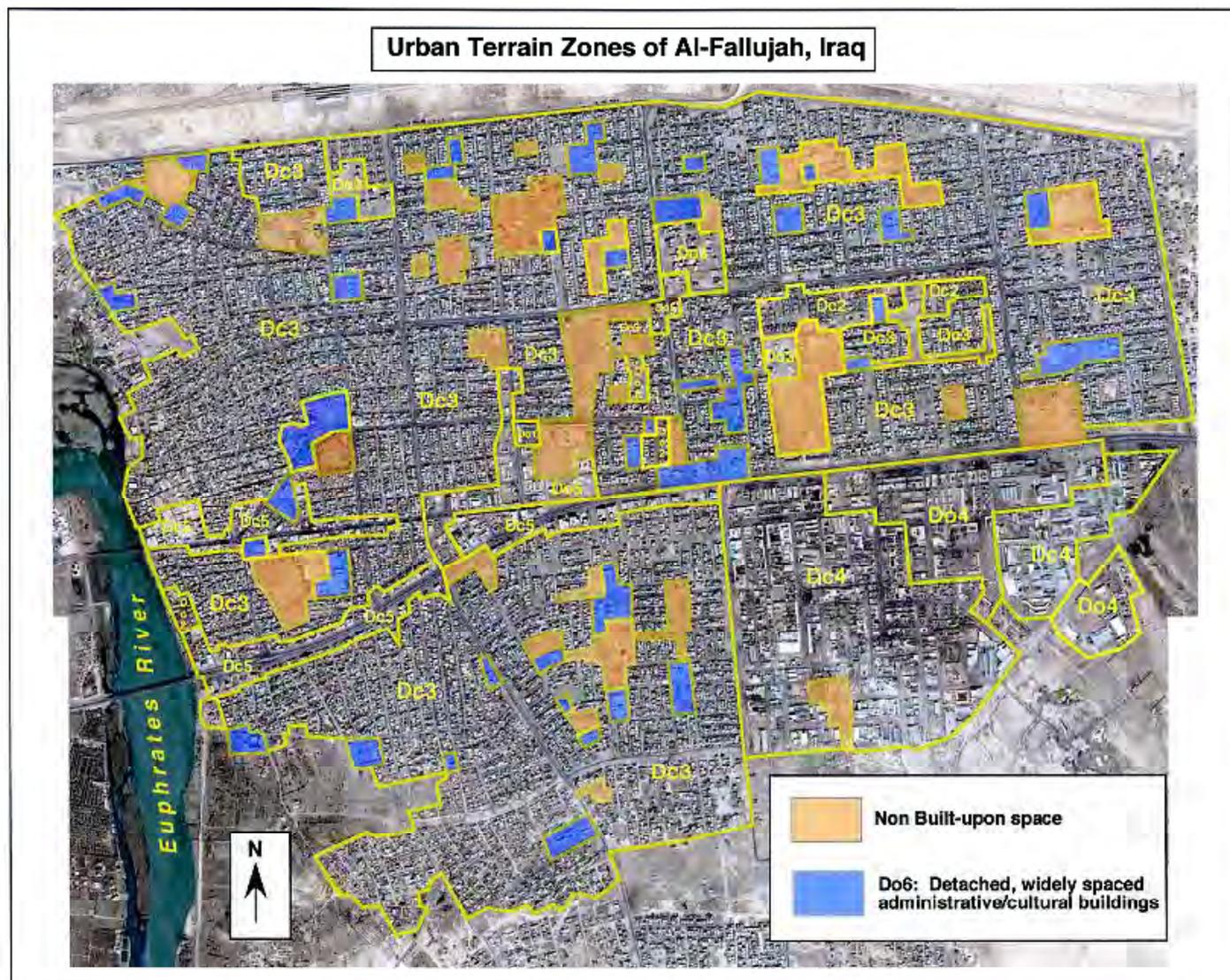


Figure 272. UTZ of Al Fallujah, Iraq.

In short, the spatial distribution of the various building types is predictable. Attached buildings occupy expensive land in the city's core and along commercial arterials extending outward. Closely spaced buildings are found near the core on quite expensive land. Widely spaced buildings are found on the least expensive land at the city's periphery or anywhere within the city as they are the product of comprehensive planning, as in an urban redeveloped area or on public space, e.g., a city or national government complex, as in Washington D.C.

The UTZ classification scheme, being a full inventory of a city's homogeneous urban areas, should not be confused with the sort of spatial models seen in such publications as FM 90-10-1 where hypothetical, broad, general zones of a city are portrayed. Examples are city core, commercial ribbon, and outlying high-rise area.

Of special value to using the 44 types of buildings in this document, each UTZ title includes the predominant building type. The complete list, organized into the three basic density groups, is found in table 2.

Urban Terrain Zone (UTZ) A1: Attached Commercial Buildings

Urban Terrain Zone A1

Building Function and Density:

Attached commercial buildings,
mainly in city centrum

Building Separation:

Attached along streets

Building Setting:

The evolved part of the city where
buildings were built one by one,
and not part of a planned whole

Building Construction Type:

Brick buildings, framed heavy clad
buildings, and some replacement
framed light clad buildings

Range of Building Heights:

5 - 50 Stories

Age:

From several hundred year old
brick buildings, to framed heavy
clads 1890-1930, to recent light
clad buildings

A1 Example: San Jose, Costa Rica



RE Photo

Figure 274. UTZ A1: attached commercial buildings.

Urban Terrain Zone (UTZ) A2: Attached Apartments and Hotels	
<p style="text-align: center;">Urban Terrain Zone A2</p> <p>Building Function and Density: Attached apartment and hotel buildings in core periphery</p> <p>Building Separation: Attached along streets</p> <p>Building Setting: The evolved part of the city where buildings were built one by one, and not part of a planned whole</p> <p>Building Construction Type: Brick buildings, framed heavy clad buildings, and some replacement framed light clad buildings</p> <p>Range of Building Heights: 5 - 10 Stories</p> <p>Age: From several hundred year old brick buildings, to framed heavy clads 1890-1930</p>	<p style="text-align: center;">A2 Example: Budapest, Hungary</p>  <p style="text-align: right;"><i>RE Photo</i></p>

Figure 275. UTZ A2: attached apartments and hotels.

Urban Terrain Zone (UTZ) A3: Attached Houses

Urban Terrain Zone A3

Building Function and Density:

Attached houses

Building Separation:

Attached along streets

Building Setting:

The evolved part of the city where buildings were built one by one, and not part of a planned whole

Building Construction Type:

Mainly brick buildings with some framed replacements

Range of Building Heights:

2-3 Stories

Age:

19th and early 20th century

A3 Example: Bremen, Germany



Figure 276. UTZ A3: attached houses.

Urban Terrain Zone (UTZ) A4: Attached Industrial/Storage Buildings

Urban Terrain Zone A4

Building Function and Density:
Attached Industrial/storage

Building Separation:
Attached

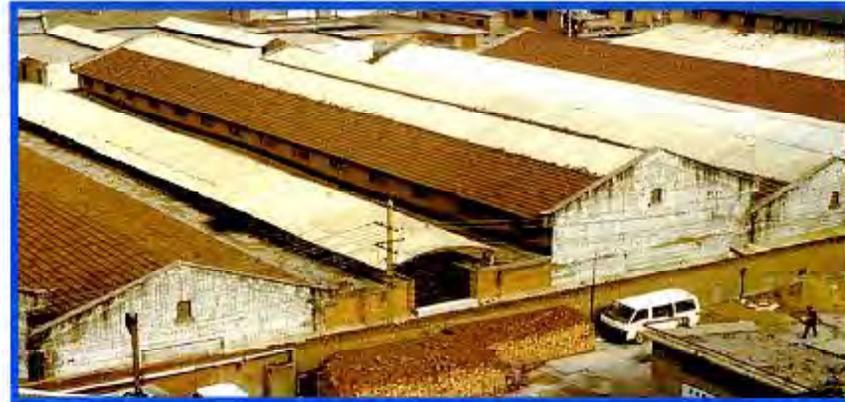
Building Setting:
Usually found near the original core of cities

Building Construction Type:
Mainly brick buildings with some framed replacements

Range of Building Heights:
2-3 Stories

Age:
19th and early 20th century

A4 Example: Xian, China



RE Photo

Figure 277. UTZ A4: attached industrial/storage buildings.

Urban Terrain Zone (UTZ) A5: Attached Commercial Buildings Along Arterial Streets

Urban Terrain Zone A5

Building Function and Density:
Attached commercial buildings
along string streets

Building Separation:
Attached

Building Setting:
Usually found near the original
core of cities and along major
streets outward from center

Building Construction Type:
Mainly brick buildings with some
framed replacements

Range of Building Heights:
2-3 Stories

Age:
19th and early 20th century

A5 Example: Quebec City



RE photo

Figure 278. UTZ A5: attached commercial buildings along arterial streets.

Urban Terrain Zone (UTZ) Dc1: Closely spaced High-rise Office Buildings

Urban Terrain Zone Dc1

Building Function and Density:

Detached, closely-spaced office buildings

Building Separation:

Less than 13 meters

Building Setting:

In newly developed areas in central city

Building Construction Type:

Framed light clad

Range of Building Heights:

High-rises, 10 to 50 Stories

Age:

Since 1950

Dc1 Example: Singapore



RE photo 2004

Figure 279. UTZ Dc1: closely spaced high-rise office buildings.

Urban Terrain Zone (UTZ) Dc2: Closely spaced Apartment Buildings

Urban Terrain Zone Dc2

Building Function and Density:

Detached, closely-spaced apartments

Building Separation:

Less than 13 meters

Building Setting:

In the first rings of suburbs outward from central city

Building Construction Type:

Framed light clad or box-wall principle (panel wall) buildings

Range of Building Heights:

5 to 30 Stories

Age:

Mainly since World War II

Dc2 Example: Cairo, Egypt



RE photo 2004

Figure 280. UTZ Dc2: closely spaced apartment buildings.

Urban Terrain Zone (UTZ) Dc3: Closely Spaced Houses

Urban Terrain Zone Dc3

Building Function and Density:

Detached, closely-spaced houses

Building Separation:

Less than 13 meters

Building Setting:

In residential areas both near the center (older) and at city edge (newer)

Building Construction Type:

Framed with various sidings (brick, wood, stucco) and mass brick, CMU, and framed with infill walls

Range of Building Heights:

1 - 3 Stories

Age:

All ages

Dc3 Example: Germany



Figure 281. UTZ Dc3: closely spaced houses.

Urban Terrain Zone (UTZ) Dc4: Closely Spaced Industrial/storage Buildings

Urban Terrain Zone Dc4

Building Function and Density:

Detached, closely spaced industrial/storage buildings

Building Separation:

Less than 13 meters

Building Setting:

At the edge of the city

Building Construction Type:

Brick, CMUs, R/C Framed with Infill walls, and Light Steel framed

Range of Building Heights:

1-4 Stories

Age:

Mainly since World War II

Dc4 Example: England



RE photo, 2004

Figure 282. UTZ Dc4: closely spaced industrial/storage buildings.

Urban Terrain Zone (UTZ) Dc5: Closely Spaced Commercial Buildings

Urban Terrain Zone Dc5

Building Function and Density:

Detached, closely spaced commercial buildings

Building Separation:

Less than 13 meters

Building Setting:

At the edge of the city

Building Construction Type:

Brick, CMUs, R/C Framed with Infill walls, and Light Steel framed

Range of Building Heights:

1-4 Stories

Age:

Mainly since World War II

Dc5 Example: Germany



Figure 283. UTZ Dc5: closely spaced commercial buildings.

Urban Terrain Zone (UTZ) Dc6: Closely Spaced Administrative/Cultural Buildings	
<p>Urban Terrain Zone Dc6</p> <p>Building Function and Density: Detached, closely spaced administrative/cultural buildings</p> <p>Building Separation: Less than 13 meters</p> <p>Building Setting: Anywhere in the city</p> <p>Building Construction Type: Brick, CMUs, and R/C Framed with Infill walls</p> <p>Range of Building Heights: 1-4 Stories</p> <p>Age: Spanning time</p>	<p>Dc6 Example: Bangkok</p>  <p><i>RE photo 2004</i></p>

Figure 284. UTZ Dc6: closely spaced administrative/cultural buildings.

Urban Terrain Zone (UTZ) Do1: Widely spaced Commercial Buildings, Shopping Centers

Urban Terrain Zone Do1

Building Function and Density:

Detached, widely spaced (> 13 meters) commercial buildings, shopping center, malls

Building Separation:

13 meter to 100 meters

Building Setting:

Located in modern, planned developments with large parking lots.

Building Construction Type:

Mass construction: tilt-ups, CMU load-bearing, poured-in-place concrete, and framed with various infill materials

Range of Building Heights:

1-3 Stories

Age:

Since about 1960

Do1 Example: U.S.



RE Photo

Figure 285. UTZ Do1: widely spaced commercial buildings, shopping centers.

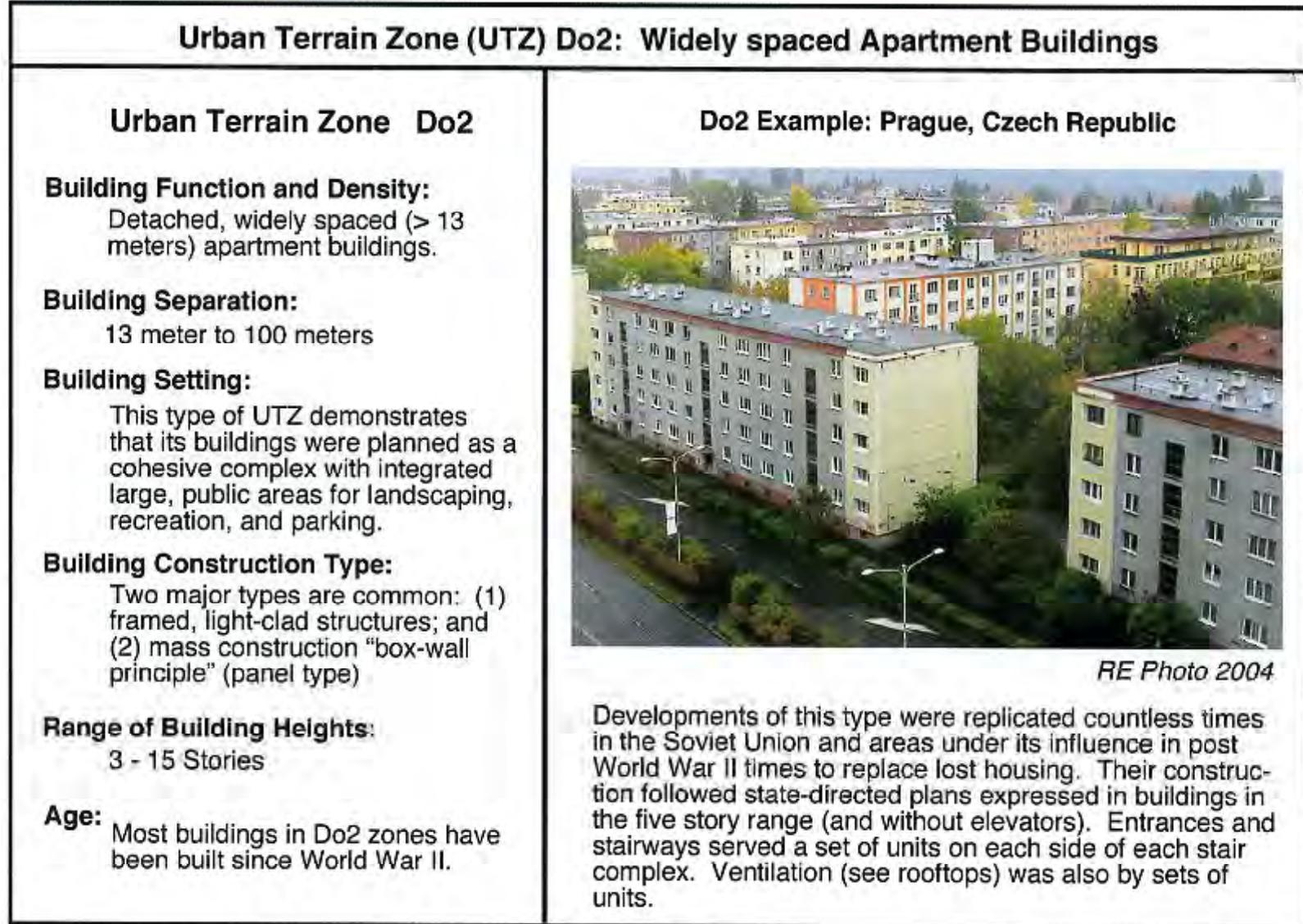


Figure 286. UTZ Do2: widely spaced apartment buildings.

Urban Terrain Zone (UTZ) Do3: Widely Spaced Houses

Urban Terrain Zone Do3

Building Function and Density:

Detached, widely spaced houses

Building Separation:

More than 13 meters

Building Setting:

At the edge of the city

Building Construction Type:

R/C Framed with Infill walls, wood framed, and concrete masonry units with veneers

Range of Building Heights:

1-3 Stories

Age:

Mainly since World War II

Do3 Example: Austria



RE photo, 2004

Figure 287. UTZ Do3: widely spaced houses.

Urban Terrain Zone (UTZ) Do4: Widely Spaced Industrial/Storage Buildings

Urban Terrain Zone Do4

Building Function and Density:

Detached, widely spaced industrial/storage buildings

Building Separation:

More than 13 meters

Building Setting:

In areas designated for industrial use, at city edge

Building Construction Type:

R/C framed with light cladding and R/C Framed with Infill walls,

Range of Building Heights:

1-3 Stories

Age:

Mainly since World War II

Do4 Example: Germany



Figure 288. UTZ Do4: widely spaced industrial/storage buildings.

Urban Terrain Zone (UTZ) Do5: Widely Spaced Commercial Buildings

Urban Terrain Zone Do5

Building Function and Density:

Detached, widely spaced commercial buildings

Building Separation:

More than 13 meters

Building Setting:

In new areas, either redeveloped in older sections or in new sections

Building Construction Type:

R/C framed with light cladding and
R/C Framed with Infill walls

Range of Building Heights:

3-15 Stories

Age:

Mainly since World War II

Do5 Example: Germany



Figure 289. UTZ Do5: widely spaced commercial buildings.

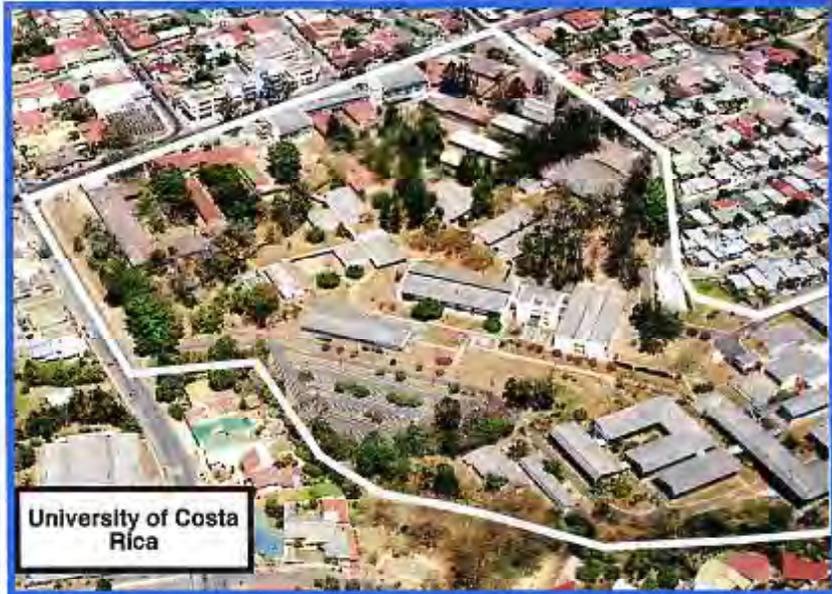
Urban Terrain Zone (UTZ) Do6: Widely Spaced Administrative/Cultural Buildings	
<p>Urban Terrain Zone Do6</p> <p>Building Function and Density: Detached, widely spaced administrative/cultural buildings</p> <p>Building Separation: More than 13 meters</p> <p>Building Setting: At various places where a society places a government center, monuments, campuses, religious centers, etc.</p> <p>Building Construction Type: Stone, brick, concrete, CMUs, R/C framed with light cladding and R/C Framed with Infill walls</p> <p>Range of Building Heights: 3-15 Stories</p> <p>Age: Spanning time</p>	<p>Do6 Example: Costa Rica</p>  <p style="text-align: right;"><i>RE Photo</i></p>

Figure 290. UTZ Do6: widely spaced administrative/cultural buildings.

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Appendix A

Global Set, Buildings with Venting as a proportion of Front Walls: Mass Construction Buildings

Note: all photographs by R. Ellefsen, unless otherwise indicated

Stone Houses: Venting



Stone House (Mass 1)

Windows 12.5 %
Doors 2.6 %
Combined 15.1 %

House located in Edinburgh, Scotland. Windows have wooden frames and sashes with small panes.

Photo: 1994



Stone House (Mass 1)

Windows 5.6 %
Doors obscured

House located near Limoge, France in a *Bastide* town. Windows have wooden frames and sashes with small panes.

Photo: 1991



Stone House (Mass 1)

Windows 5.9 %
Doors 2.2 %
Combined 8.1 %

House is located in Hammelburg, Germany. Windows have wooden frames and sashes with small panes.

Photo: 1980



Stone House (Mass 1)

Windows 4.6 %
Doors 4.5 %
Combined 9.1 %

House located in Castellina, Tuscany, Italy. Structure shows indications of having been modified several times.

Photo: 2004



Stone House (Mass 1)

Windows 6.9 %
Doors not visible

House located in Salzgitter, Germany. Vertically aligned windows have arched reinforcement wooden frames, small panes.

Photo 1980



Stone House (Mass 1)

Windows 11.4 %
Doors.8 %
Combined 12.2 %

Manor House located in Wilton, England. Windows have wooden frames and sashes with small panes.

Photo: 1993

Adobe House: Venting



Adobe House (Mass 3)

Windows 6.5 %
Doors 5.8 %
Combined 12.3 %

House located in Luxor,
Egypt.

Photo: 2004

Brick Houses: Venting



Brick House (Mass 5)

Windows 14.1 %
Doors 2.8 %
Combined 16.9 %

House, located in Koblenz, Germany is a duplex, one unit on floor one and two plus a small apartment in the attic.

Photo: 2004 by Dave Fordyce, ARL



Brick House (Mass 5)

Windows 9.6 %
Door 5.3 %
Combined 14.9 %

House located in Elburz
Mountains near Caspian
Sea.

Photo: 1967



Brick House (Mass 5)

Windows 17.9 %
Door 2.8 %
Combined 20.7 %

House located in Uppsala, Sweden. House has classical vertical alignment of windows.

Photo: 1992



Brick House (Mass 5)

Windows 15.3 %
Door 3.4 %
Combined 18.7 %

House in Bremen, Germany. Note uniform windows.

Photo: 1999



Brick House (Mass 5)

Windows 22.3 %
Door not visible

House in Bremen, Germany. Arches over basement windows reveal brick construction.

Photo: 1999



Brick House (Mass 5)

Windows 13.6 %
 Doors 2.6 %
 Combined 16.2 %

House in Juarez, Chihuahua,
 Mexico

Photo: 1999



Brick House (Mass 5)

Windows 7.4 %
 Doors 4.6 %
 Combined 12.0 %

House in Andean village, Peru

Photo: 1980



Brick House (Mass 5)

Windows 15.4 %
 Doors not visible

House in a North China village, near
 Xian

Photo: 1997



Brick House (Mass 5)

Windows 12.8 %
 Door 9.2 %
 Combined 15.8 %

House converted to a store in San Jose,
 Costa Rica. "Dog House" dormer on rusted
 corrugated steel roof has a swinging sash
 window.

Photo: 1994



Brick House (Mass 7)

Windows 15.5 %
Door 4.8 %
Combined 20.3 %

House is in Baltimore, MD, USA. Note vertical window alignment, wooden sashes and frames, and small panes.

Photo: 1988



Brick House (Mass 5)

Windows 10.2 %
Door 2.6 %
Combined 12.8 %

House in Norrköping, Sweden.

Photo: 1992



Brick House (Mass 5)

Windows 12.5 %
Door 3.3 %
Combined 15.8 %

House in Bremen, Germany. Note French doors. Frames and sashes are wooden.

Photo: 1999



Brick Row House (Mass 7)

Windows 12.3 %
Doors 6.1 %
Combined 18.4 %

Building is in Vienna, Austria. It has a door for each set of five apartments.

Photo: 2004



Brick Row House (Mass 7)

Windows 16.5 %
Doors 6.3 %
Combined 22.8 %

Building is in Bremen, Germany. Door and windows have wood frames.

Photo: 1999



Brick Row House (Mass 7)

Windows 5.4 %
Doors 1.3 %
Combined 6.7 %

Building is in Lebenstedt, Salzgitter, Germany. It is part of a development built in the 1930s to house steel workers.

Photo: 1982



Brick Row House (Mass 7)

Windows 12.3 %
Doors 9.0 %
Combined 21.3 %

Building is in Wilton, England. It is typical of factory workers' housing in the nineteenth century.

Photo: 1993



Brick Row House (Mass 7)

Windows 14.7 %
Doors 12.6 %
Combined 27.3 %

Building is near Guilin, China

Photo: 1996



Brick Row House (Mass 7)

Windows 11.4 %
Doors 4.3 %
Combined 15.7 %

Building is in Stratford, England, another typical English row house.

Photo: 1993



CMU House (Mass 14)

Windows 12.2 %
Door 2.3 %
Combined 14.5 %

Building is in Bremen, Germany. It is being constructed as a replacement for a brick house

Photo: 1999



CMU House (MASS 14)

Windows: 15.3 %
Doors 2.7 %
Combined 18.0 %

Building is in Lebenstadt, Salzgitter, Germany. CMUs are light-weight foamed concrete.

Photo: 1982



CMU House (Mass 14)

Windows 9.1 %
Doors 3.8 %
Combined 12.9 %

House is in Puntarenas, Costa Rica. CMUs are covered with stucco in front.

Photo: 1982



CMU House (Mass 14)

Windows 11.1 %
Door not visible

Building is in Salzgitter, Germany. Blocks are typical, in Germany, large dimension foam.

Photo: 1982



CMU House (Mass 14)

Windows 9.2 %
Doors 4.1 %
Combined 13.3 %

House in Puntarenas,
Costa Rica

Photo: 1980



CMU House (Mass 14)

Windows 3.9 %
Doors 6.3 %
Combined 10.2 %

House is in Lima, Peru,
built on the slopes of the
Andes in the eastern
part of the city.

Photo: 1980

Brick Apartment Buildings: Venting



Brick Apartment Building (Mass 8)

Windows 11.6 %
Doors 9.8 %
Combined 21.4 %

Building in Budapest, Hungary. Apartments on upper floor undergoing renovation. Entry doorway into a corridor is made of wood

Photo: 2004



Brick Apartment Building (Mass 8)

Windows 13.6 %
Doors 3.7 %
Combined 17.3 %

Building is in Koblenz, Germany. Classic windows are center open topped by a single pane.

Photo by Dave Fordyce, ARL, 2004



Brick Apartment Building (Mass 8)

Windows 11.6 %
Doors 2.1 %
Combined 13.7 %

Building in Uppsala, Sweden. Apartments occupy upper floors, retail store on ground floor.

Photo: 1992



Brick Apartment Building (Mass 8)

Windows 13.1 %
Doors 1.4 %
Combined 14.5 %

Building is in Koblenz, Germany Windows follow classic style.

Photo by Dave Fordyce, ARL, 2004



Brick Apartment Building (Mass 8)

Windows 13.9 %
Doors 2.1 %
Combined 16.0 %

Building is in Koblenz, Germany

Photo by Dave Fordyce, ARL, 2004



Brick Apartment Building (Mass 8)

Windows 16.8 %
Doors 3.4 %
Combined 20.2 %

Building in Rome, Italy. Vertically aligned windows help identify the building as having brick construction.

Photo: 1993



Brick Apartment Building (Mass 8)

Windows 16.9 %
Door 3.6 %
Combined 20.5 %

Building is in Bath, England. Windows are longer and narrower than those found on the continent.

Photo: 1993



Brick Apartment Building (Mass 8)

Windows 10.4 %
Door 6.2 %
Combined 16.6 %

Building is in Mumbai (Bombay), India.

Photo: 1967



Brick Apartment Building (Mass 8)

Windows 10.4 %
Door 5.4 %
Combined 15.8 %

Building in Linz, Austria. Baroque decorations don't disguise the standard window types.

Photo: 1991

Box Wall Principle Apartment Buildings



Box Wall Principle Apartment Building (Mass 22)

Windows 13.7 %
Doors 5.5 %
Combined 19.2 %

Building in Prague, Czech Republic. Structure is a typical Soviet style building.

Photo: 2004



Box Wall Apartment Building (Mass 22)

Windows 23.5 %

Building in East Berlin, Germany

Photo 1980



Box Wall Apartment Building (Mass 22)

Windows 28.3 %

Building in East Berlin, Germany. Each apartment unit has a veranda. Windows and door occupy most of one end of the "box."

Photo: 1980



Box Wall Apartment Building (Mass 22)

Windows 26.7 %

Building in West Berlin. Apartment units have large windows for the daytime occupancy rooms and small windows for bedrooms.

Photo: 1980



Box Wall Apartment Building (Mass 22)

Windows 34.3 %

Building in Philadelphia, PA, USA. Each cell has large windows and a door entry to the veranda.

Photo: 1985



Box Wall Apartment Building (Mass 22)

Windows 18.8 %

Building in Braunschweig, Germany.

Photo: 1983

Brick Hotels: Venting



Brick Hotel (Mass 9)

Windows 16.3 %
Doors 2.8 %
Combined 19.1 %

Building is in Vienna, Austria. Windows on upper three floors measure one by one and a half meters.

Photo: 2004



Brick Hotel (Mass 9)

Windows 18.4 %
Doors 3.4 %
Combined 21.8 %

Building is in Reims, France. Note lack of windows at strong corner of this brick structure, in accordance with basic theory. Building has a Mansard roof, a device to reduce taxes based on a full floor.

Photo: 1993



Brick Hotel (Mass 9)

Windows 15.1 %
Doors 2.6 %
Combined 17.7 %

Each of the upper floor windows serves but a single room, indicating rather common narrow guest rooms in hotels of this class.

Photo: 1999



Brick Hotel (Mass 9)

Windows 12.4 %
Doors 3.3 %
Combined 15.7 %

Building is in Falkenberg, Germany. Windows are variations of the European standard.

Photo: 1983



Brick Hotel (Mass 9)

Windows 22.1 %
Doors 5.3 %
Combined 27.4 %

Building is in Helsingborg, Sweden. Note brick arches over windows to replace wall's lost integrity.

Photo: 1983

Brick Office Buildings: Venting



Brick Office Building (Mass 10)

Windows 14.3 %
Doors 2.3 %
Combined 16.6 %

Building is in Helsinki, Finland in the Empire style.

Photo: 1976



Brick Office Building (Mass 10)

Windows 19.2 %
Doors 4.5 %
Combined 23.7 %

Building, a government office building, is in Vienna, Austria.

Photo: 2004



Brick Office Building (Mass 10)

Window 11.6 %
Doors 4.9 %
Combined 16.5 %

Building, a remnant of British colonial days, is in Singapore.

Photo: 2004



Brick Office Building (Mass 10)

Windows 16.9 %
Doors 3.4 %
Combined 20.3 %

Building is in Bremen, Germany

Photo: 1999



Brick Office Building (Mass 10)

Windows 12.3 %
Doors 3.7 %
Combined 16.0 %

Building is in Lima, Peru

Photo: 1980



Brick Office Building (Mass 10)

Windows 20.5 %
Door 1.9 %
Combined 22.4 %

Building is in Uppsala, Sweden

Photo: 1993



Brick Office Building (Mass 10)

Windows 16.8 %
Doors 2.8 %
Combined 19.6 %

Building is in Wellington, New Zealand. Note: windows are narrower than those in German buildings.

Photo: 1995



Brick Office Building (Mass 10)

Windows 9.9 %

Building is in Koblenz, Germany

Photo by Dave Fordyce, ARL
2004



Brick Office Building (Mass 10)

Windows 13.4 %
Doors 1.3 %
Combined 14.7 %

Building, a government office, is in Bath, England

Photo: 1992

Masonry Industrial/storage Buildings: Venting



Brick Industrial/storage Building (Mass 13)

Windows 22.1 %
Doors 0.7 %
Combined 22.8 %

Building is in Norrköping, Sweden. Note arches over windows and joist-end plates in walls

Photo 1995



Brick Industrial/storage Building (Mass 13)

Windows 17.4 %

Building, in Shanghai, is concrete, note pilasters. Uses open windows for ventilation

Photo: 1996

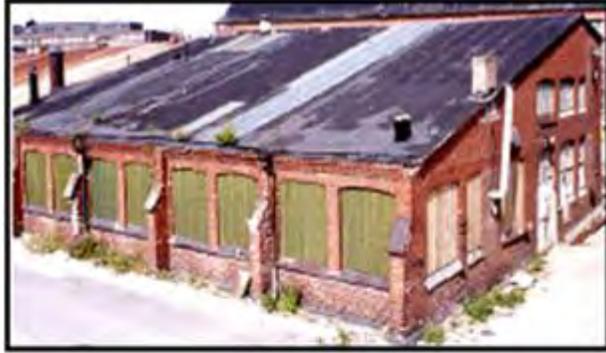


Brick Industrial/storage Building (Mass 13)

Windows 16.8 %

Building is in Stavanger, Norway. Note arches over windows and small panes

Photo: 1976



Brick Industrial/storage Building (Mass 13)

Windows 27.4 %
Doors 1.7 %
Combined 29.1 %

Building is in Helsinki, Finland

Photo: 1976



Brick Industrial/Storage Building (Mass 13)

Windows 6.4 %
Doors 7.9 %
Combined 14.3 %

Building is in Singapore, an old "godown," remnant of British days (probably no longer standing)

Photo: 1984

Large Masonry Buildings, Churches and Mosques



Mosque (Mass 12)

Windows 11.8 %
Doors 4.4 %
Combined 16.2 %

Friday Mosque in Delhi, India

Photo: 1967



Temple (Mass 12)

Windows 6.7 %
Doors 2.4 %
Combined 9.1 %

Building is in Bangkok, Thailand

Photo: 2004



Islamic Religious Building (Mass 12)

Windows 5.4 %
Doors 6.1 %
Combined 11.5 %

Building is in Chinai (Madras), India, an example of the propagation of Islamic Architecture to the southern end of the Indian sub-continent.

Photo: 1967



Mosque (Mass 12)

Windows 1.6 %
Doors 6.8 %
Combined 8.4 %

Building is in Teheran, Iran. The small proportion of venting is typical.

Photo: 1967



Church (Mass 2)

Windows 17.2 %
Doors 1.8 %
Combined 19.0 %

Building is in Strasbourg, France. Windows do not provide air circulation.

Photo: 2002



Church (Mass 12)

Windows 4.6 %
Doors 1.6 %
Combined 6.2 %

Building is a Roman Catholic Church in Heredia, Costa Rica

Photo: 1994



Church (Mass 2)

Windows 14.1 %
Doors 4.5 %
Combined 18.6 %

Building is a Church of England cathedral in Canterbury, England

Photo: 1993



Church (Mass 2)

Windows 7.1 %
Doors 1.3 %
Combined 8.4 %

Church is in Koblenz, Germany

Photo by Dave Fordyce, ARL, 2004



Church (Mass 2)

Windows 8.3 %
Doors 1.9 %
Combined 10.2 %

Building is a cathedral in Chartes, France, known for its stained glass windows.

Photo: 1995



Church (Mass 2)

Windows 19.1 %

Building is a cathedral in Paris, known for its flying buttresses to support its tall, narrow structure.

Photo: 1995



Church (Mass 12)

Windows 10.2 %
Doors 3.1 %
Combined 13.3 %

Building is a Roman Catholic church on St. Thomas Mount in southern Chennai (Madras), India

Photo: 1958



Religious Building (Mass 2)

Windows 2.6 %
Doors 2.2 %
Combined 4.8 %

This stone structure is in Jerusalem, Israel

Photo: 1983

Framed Construction Buildings

Wood Framed Houses: Venting



Wood Framed House (Framed 3)

Windows 11.2 %
Doors 3.1 %
Combined 14.3 %

House is in Stavanger, Norway

Photo: 1976



Wood Framed House (Framed 3)

Windows 7.8 %

Building is in Kuala Lumpur,
Malaysia

Photo: 1984



Wood Framed House (Framed 3)

Windows 9.5 %
Doors 3.8 %
Combined 13.3 %
Building is in Imeln,
Sweden
Photo: 1983



Wood Framed House (Framed 3)

Windows 7.9 %

Building in Helsinki,
Finland is of a traditional
style

Photo: 1983



Framed, Curtain Wall Apartment: Venting (Framed 8)

Windows 17.6 %

Building is in Macao. Larger windows are for daytime occupancy, smaller ones for bedrooms and kitchens.

Photo: 1997



Framed, Curtain Wall Apartment: Venting (Framed 8)

Windows 13.3 %

Building is in Lisbon, Portugal. Window size varies, as in above photo.

Photo: 1991



Framed, Curtain Wall Apartment: Venting (Framed 8)

Windows 24.7 %
Doors 8.3 %
Combined 33.0 %

Building is in London, England

Photo: 1991



Framed, Curtain Wall Apartment: Venting (Framed 8)

Windows 39.4 %

Building is in Rotterdam, Netherlands

Photo by Glenn Schumacher, 1980



**Framed, Curtain Wall Apartment:
(Framed 8)**

Windows 39.4 %

Building is in Panama City, Panama

Aluminum frames separate large panes in each module.

Photo: 1999



**Framed, Curtain Wall Apartment:
(Framed 8)**

Windows 34.1 %

Building is in Hong Kong. Each apartment unit is fully vented at its outside wall.

Photo: 1983

Framed Heavy Clad Hotels: Venting



Framed, Heavy Clad Hotel (Framed 6)

Windows 20.4 %

Building is in Denver, Colorado

Each guest room has a window.

Photo: 1996



Framed, Heavy Clad Hotel (Framed 6)

Windows 16.2 %
Doors 4.7 %
Combined 20.9 %

Building is in Tunis, Tunisia, classic hotel from French colonial days

Photo: 1984



Framed, Heavy Clad Hotel (Framed 6)

Windows 18.8 %
Doors 1.9 %
Combined 20.7 %

Building is in Ho Chi Minh City (then Saigon). Shutters in windows are typical in tropical areas.

Photo: 1958



Framed, Heavy Clad Hotel (Framed 6)

Windows 12.1 %
Doors 1.4 %
Combined 13.5 %

Building is in San Jose, Costa Rica. Windows use wooden sashes.

Photo: 1994



Framed, Heavy Clad Hotel (Framed 6)

Windows 17.4 %
Doors 1.4 %
Combined 18.8 %

Building is in Singapore, the famous Raffles

Photo 2004



Framed Heavy Clad Hotel (Framed 6)

Windows 30.9 %
Doors 1.1 %
Combined 32.0 %

Building is in Hong Kong

Photo: 2004



Framed Heavy Clad Hotel (Framed 6)

Windows 14.9 %
Doors 3.4 %
Combined 18.3 %

Building is in Tokyo, Japan. Its replacement is a framed, light clad structure with larger windows.

Photo: 1984



Framed Heavy Clad Hotel (Framed 6)

Windows 12.4 %
Doors 1.6 %
Combined 14.0 %

Building is in Paris, France

Photo 1992



Framed Heavy Clad Hotel (Framed 6)

Windows 21.8 %

Building is in Colombo, Sri Lanka. Smallish windows are similar to those seen in Brick hotels.

Photo: 2004

Framed Light Clad Apartments with Infill Windows



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 15.6 %
Doors 3.3 %
Combined 18.9 %

Building is in San Jose, Costa Rica

Photo: 1994



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 12.4 %
Doors 3.4 %
Combined 15.8 %

Building is in New Delhi, India.
Window setback provides valuable shade

Photo: 1967



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 21.5 %
Doors 6.1 %
Combined 27.6 %

Building is in Guilin, China

Photo: 1997



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 19.9 %

Building is in Cairo, Egypt

Photo: 2004



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 9.9 %

Doors 2.2 %

Combined 12.1 %

Building is in Tel Aviv, Israel

Photo: 1999



Framed Light Clad Apartment with Infill Windows (Framed 8)

Windows 14.6 %

Building in Gibraltar

Photo: 1991

Framed Light Clad Curtain Wall Hotels: Venting

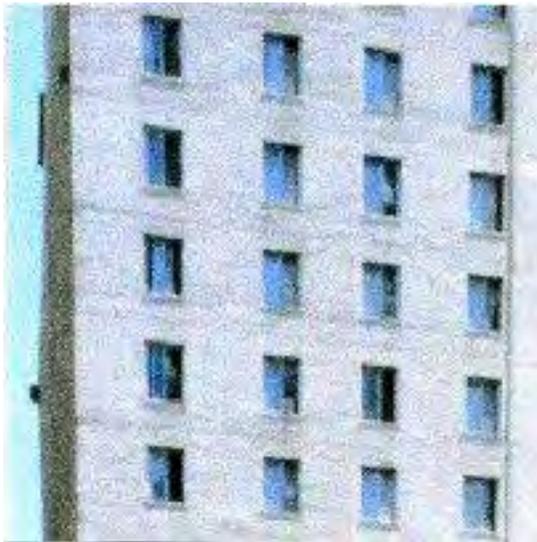


Light Clad Curtain Wall Hotel (Framed 9)

Windows 13.3 %
Door 2.0 %
Combined 15.3 %

Building is in Uppsala, Sweden. Small size of rooms are apparent from the window spacing. Windows tilt vertically to open.

Photo: 1992



Light Clad Curtain Wall Hotel (Framed 9)

Windows 10.7 %

Building in California

Photo: 1989



Light Clad Curtain Wall Hotel (Framed 9)

Windows 44.2 %

Building is in Macao (now China). Windows occupy most of end wall of each guest room.

Photo: 1996

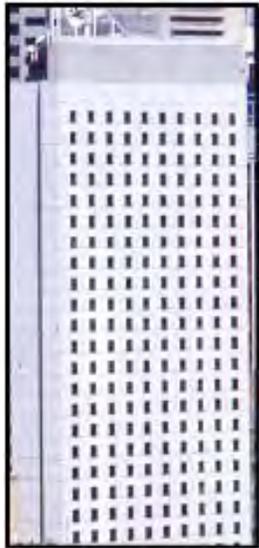


Light Clad Curtain Wall Hotel (Framed 9)

Windows 23.8 %

Building is in Edmonton, Alberta, Canada.
Mullions separate windows.

Photo: 1982



Light Clad Curtain Wall Hotel (Framed 9)

Windows 14.3 %

Building is in Sydney, New South Wales,
Australia. Window style falls into the class of
“minimum.”

Photo: 1992



Light Clad Curtain Wall Hotel (Framed 9)

Windows 24.4 %

Building is in Shanghai, China.

Photo: 1996

Framed Light Clad Infill Wall Hotel: Venting



Light Clad Infill Wall Hotel (Framed 9)

Windows 33.2 %

Building is in Bangkok, Thailand. Sliding glass window/door provides access to deck for each guest room.

Photo: 2004



Light Clad Infill Wall Hotel (Framed 9)

Windows 15.9 %

Building is in Singapore. Again, note window-glass window/door for entry onto deck.

Photo: 2004



Light Clad Infill Wall Hotel (Framed 9)

Windows 35.3 %
Doors 2.6 %
Combined 37.9 %

Building is in Guilin, China. Note mullions separating guest rooms.

Photo: 1996

Framed Light Clad Curtain Wall Office Building: Venting



**Light Clad Curtain Wall Office Building
(Framed 10)**

Windows: 50.0%

Building is in Bangkok, Thailand. Open tilting windows suggest either building has no air conditioning or occupants choose not to use it.

Photo: 1983



**Light Clad Curtain Wall Office Building
(Framed 10)**

Windows 42.4 %

Doors 1.4 %

Combined 43.8 %

Building is in Stavanger, Norway. Windows are in a spandrel pattern.

Photo: 1976



**Light Clad Curtain Wall Office Building
(Framed 10)**

Windows 32.2 %

Building is in Manila, Philippines. Spandrel pattern is seen again.

Photo: 1981



**Light Clad Curtain Wall Office Building
(Framed 10)**

Windows 16.3 %

Building is in Uppsala, Sweden

Photo: 1994



Light Clad Curtain Wall Office Building (Framed 10)

Windows 28.4 %

Building is in Haifa, Israel. Spandrels.

Photo: 1999



Light Clad Curtain Wall Office Building (Framed 10)

Windows 56.7 %

Doors 2.7 %

Combined 59.4 %

Building in Tel Aviv, Israel. Photo: 1999



Light Clad Curtain Wall Office Building (Framed 10)

Windows 28.5 %

Doors 3.7 %

Combined 32.3 %

Building is in Prague, Czech Republic.

Photo: 2004



Light Clad Curtain Wall Office Building (Framed 10)

Windows 56.3 %

Doors 1.5 %

Combined 57.8 %

Building is in Koblenz, Germany

Photo by Dave Fordyce, ARL, 2004



Light Clad Curtain Wall Office Building (Framed 10)

Windows 58.8 %

Building is in Hong Kong. Another example of the popular spandrel type of window pattern.

Photo: 2004

Framed Light Clad Infill Wall Office Building: Venting



Light Clad Infill Wall Office (Framed 10)

Windows 28.3 %

Doors 1.7 %

Combined 30.3 %

Building in Lima, Peru

Photo: 1980



Light Clad Infill Wall Office (Framed 10)

Windows 17.2 %

Doors 2.8 %

Combined 20.0 %

Building is in Manila, Philippines. Note again the provision of shade for tropical area buildings.

Photo: 1981



Light Clad Infill Wall Office (Framed 10)

Windows 25.9 %

Building is in Salzgitter, Germany. Tilt windows are seen.

Photo: 1999



Light Clad Infill Wall Office (Framed 10)

Windows 17.7 %
Doors 1.9 %
Combined 19.6 %

Building is in Chennai (Madras), India.

Photo: 1967



Light Clad Infill Wall Office (Framed 10)

Windows 34.9 %

Building is in Salzgitter, Germany. Visible partitions as seen through windows reveal different size office units.

Photo: 1999



Light Clad Infill Wall Office (Framed 10)

Windows 11.3 %
Doors 1.3 %
Combined 12.6 %

Building is in San Jose, Costa Rica. Again, smallish windows are seen in a tropical environment.

Photo: 1994

Light Steel Framed Industrial/Storage Buildings: Venting



Steel Framed I/S Building (Framed 20)

Windows 5.2 %
Doors 8.7 %
Combined 13.9 %
Building in Bangkok, Thailand. Photo 2004



Steel Framed I/S Building (Framed 20)

Windows 4.1 %
Open end.
Building in Tokyo, Japan.

Photo 1967



Steel Framed Industrial/storage Building (Framed 20)

Windows 5.1 %

Building is in
Salzgitter, Germany

Minimum lighting but
maximum security
afforded by small
windows.

Photo: 1983



**Steel Framed
Industrial/Storage
Building (Framed 20)**

Windows 7.2 %

Building is in
Switzerland, near
Zurich

Photo: 2004



**Steel Framed
Industrial/Storage
Building (Framed 20)**

Windows 2.1 %
Doors 20.4 %
Combined 22.5 %

Building is in Uppsala,
Sweden

Photo: 1992



**Steel Framed
Industrial/Storage
Building (Framed 20)**

Windows 2.9 %

Building is in Uppsala,
Sweden

Photo: 1992

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Glossary

- Ashlar Stone** a thin slab of squared stone, used for facing or building
- Balloon frame construction** involves the employment of small dimension studs set closely together (16 inch centers in the U.S.) to form the support for a wall
- Box-wall (aka panel) construction** construction of a building using walls and floor/ceilings to form five sides of a "box," used commonly for hotels and apartments where room size is designed to remain stationary
- Brick veneer** where only stretchers are exposed on a wall and the bricks cover either a mass construction wall or are used as sheathing over a framed wall
- Brick wall width terminology** double brick refers to a brick wall the length of two headers (some 8" in the U.S., and 12 cm abroad); triple brick refers to a thickness equivalent of three headers, plus mortar; quadruple brick refers to a thickness equivalent of four headers, plus mortar, and so on with each brick increment
- Capital** The ornamental top of stone column, also applied to the decorated top floor of a classic styled building, either masonry or framed heavy-clad
- Cladding** The material covering the frame of either a steel heavy-clad structure or a steel or reinforced concrete frame light-clad structure
- CMU** A concrete masonry unit, commonly referred to as a concrete block, or cinder block (even when the material is concrete and does not contain any light-weight volcanic [cinder] material) Sizes vary internationally but the dimensions used in this report are 40 cm long by 20 centimeters deep and 20 centimeters tall
- Corbel** A bracket of stone, wood, brick, or other building material, projecting from the face of a wall and generally used to support a cornice, an arch, or a beam or concrete floor
- Dowel** A usually round pin that fits tightly into a corresponding hole to fasten or align two adjacent pieces
- English Bond** A form of laying brick where rows of headers alternate with rows of stretchers

Flemish Bond A form of laying brick where a header and a stretcher are alternated

Framed Construction Use of wood, steel, reinforced concrete columns and beams to support loads

Grout Various cement-based materials poured around rebar in cavities in concrete masonry units to provide strength and to tie CMU's together

Half-timbered Construction Where braced squared wooden columns and beams support a structure, and where wattle and daub and other materials are used as infill

Header The end of a single brick

Heavy cladding Where a combination of materials — terra cotta, stiffening, and brick or stone — cover a steel framed structure with the purpose of protection against the elements, stiffening of the frame, and giving the appearance of a masonry structure

Infill Non load-bearing material placed between columns and beams, and floor-ceilings, in a framed structure, to protect from the elements (see cover photo example)

Light cladding Involves use of a variety of light-weight, and thin, materials to cover either a steel framed structure or a steel-reinforced concrete framed structure; material may be glass, metal, a composite, lightweight foamed concrete, or a thin sheet of stone

Lintel A horizontal beam placed above a door or window in a mass construction building to support the load above, and to replace the wall integrity that has been lost by removing some of it for the window or door

Mass Construction Use of stone, brick (kiln-dried or sun dried), structural grade terra cotta, poured-in-place or panel concrete walls, or even wood in a solid log structure, where the walls of a structure are load-bearing thus supporting dead loads and live loads

Mortar A mixture of cement or lime mixed with sand and water that is used in building

Mortise A cavity, usually rectangular, in a piece of wood, stone, or other material, prepared to receive a similarly shaped projection or tenon of another piece, to hold the two together

Mud Bricks Blocks made of a local clay in a mold and strengthened with a variety of materials, usually straw, and then cured in the sun. Sizes are larger than kiln-dried bricks, often about 30 by 15 by 5 centimeters

Pediment Literally the foot, or base of a classic Greek column. The term is used here to refer to the ornamented ground floor of a Framed Heavy-clad structure, one that is taller (to about 7 meters) than the upper floors (at about 3 meters each)

Perimeter Foundation A mass construction base for a structure, made of either reinforced concrete or stone upon which other building material is constructed

Pilaster A column set into a wall to add strength and stability; pilasters are commonly employed with poured-in-place concrete walls

Pinons Shaped ends of a wooden beam inserted into a mortise, and connected with dowels

Platform Framed Construction Similar to Balloon Framed construction but employing a platform floor at each floor level, rather than having columns extend the full height of the structure

Plinth A solid pedestal foundation or base on which to rest a wall

Post and Beam Wood Construction As with half-timbered structures, walls are supported by fairly wide-spaced columns, tied to the foundation and to beams. Columns are larger in dimension than those used in balloon construction and are placed farther apart. Many older wooden structures in the U.S. and abroad have used this method of construction.

Purlin One of several horizontal members supporting the rafters of a roof

Rebar Steel rods placed in concrete to provide strength and to prevent failure in the event of breakage of the concrete; sizes and density vary with need

Reinforced concrete The abbreviation R/C is used in this report; reinforcement is achieved either with rebar or steel mesh (in the case of walls or floor/ceilings)

Rubble Stone Irregularly placed stones formed into a wall with varying amounts of mortar poured among them

Running Bond A type of laying bricks in a wall where a row of headers is exposed at the outer surface of the wall every fifth or sixth course

Shaft The main part of a classic columns (between pediment and capital) and also used to refer to the many floors of a framed heavy-clad building lying between the pediment floor, at ground level, and the capital floor

Sheathing A layer of boards or of other wood or fiber materials applied to the outer studs, joists, and rafters of a building to strengthen the structure and serve as a base for an exterior weatherproof cladding

Soldier A brick laid in a vertical position in a wall

Stretcher The length of a brick

Stucco A durable finish for exterior walls, applied wet and usually composed of cement, sand, or lime

Terra Cotta A hard, semi-fired, waterproof ceramic tile used in building construction

Tilt-up Construction Where the walls of a building are either poured on the structure's floor or delivered from off-site and then "tilted up" into a vertical position, and then diagonally braced temporarily by steel poles prior to being anchored by rafters and roof

Venting Refers to both windows and doors of a building

Wattle and Daub Wattle refers to poles intertwined with twigs, reeds, or branches for use as walls: daub refers to the mud mix that covers the wattle wall

Wythe One masonry unit thick

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