Interim Overview of GEM Building Taxonomy V2.0

Report produced in the context of the GEM Building Taxonomy Global Component

Version 1.0 – December 2012

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TABLE OF CONTENTS

1 Background

As part of the Global Earthquake Model (GEM) initiative, several projects related to physical earthquake risk estimation are underway. Each project covers a specific research component of the global earthquake risk estimation problem, such as i) the development of a global exposure database (GED4GEM[1]), ii) development of an earthquake consequence database of past earthquakes (GEMECD[2]), iii) development of seismic vulnerability functions (Global Vulnerability Consortium[3]) and iv) development of tools or toolkit for inventory and vulnerability data collection (IDCT[4]). These four components are trying to address several questions pertaining to understanding the global building stock, mapping the building stock inventory and their vulnerability characteristics, documenting their performance in past earthquakes, and developing tools to compile/document such characteristics using consistent processes worldwide.

The development of a global earthquake risk model requires a solid methodological foundation and terminology to achieve a shared understanding across the many fields and endeavours GEM will address. Global building stock is highly heterogeneous in terms of design and construction practices, and vulnerability to natural hazards. A common terminology or *taxonomy* is critical to document variations in building design and construction practices around the world. A comprehensive taxonomy is required to serve the needs of various GEM Risk components, and is used for risk estimation in the GEM project.

Key tasks in the taxonomy development process were: i) to review existing taxonomies, ii) to develop an initial taxonomy, and iii) to verify the taxonomy on a global level. An initial version of the proposed GEM Building Taxonomy (Beta Version 0.1) was released in April 2011[5], following the discussions and critique at the first Workshop held in Berkeley (March 3 and 4, 2011). The Taxonomy was substantially revised following the feedback received from the GEM Global Component project teams in April and May 2011. Version 1.0 of the GEM Building Taxonomy released in March 2012[6] and it contained eight key attributes describing a building. The taxonomy was further revised and the current version 2.0 was created following the feedback received from the GEM researchers in September and October 2012. The final Version 2.0 GEM Building Taxonomy report is currently under development and a draft version will be available in January 2013.

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[1] http://www.globalquakemodel.org/risk-global-components/exposure-database
[2] http://www.globalquakemodel.org/risk-global-components/consequence-database
[3] http://www.globalquakemodel.org/risk-global-components/vulnerability-estimation
[4] http://www.globalquakemodel.org/risk-global-components/inventory-capture
[5] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/posts/gem-basic-building-taxonomy-beta-v1.0
[6] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/posts/updated-gem-basic-building-taxonomy-v1.0

2 General Requirements

First and foremost, the building taxonomy should meet the needs of various GEM user groups. Considering the open nature of GEM, the taxonomy should meet information needs of current users, but also have the ability to expand based on needs of future users. On one hand, users should be able to collect information in sufficient detail (provided that such information is available). On the other hand, the taxonomy should be manageable (not overwhelming); that is, a balance between the depth (extent of detail) and coverage should exist. The Taxonomy team recognizes the magnitude and complexity of the effort associated with developing a global building taxonomy for multiple user groups with diverse needs and backgrounds.

The GEM Building Taxonomy has been shaped by the following key considerations:

1. ***Collapsible***. Taxonomy is judged to be collapsible if taxonomic groups with different levels of details and significance can be combined and/or compacted and the resulting combinations still distinguish differences in seismic performance, while acknowledging some loss of precision.
2. ***Detailed***. The taxonomy must include all features relevant to the seismic performance of a building located anywhere in the world. The final Detailed Taxonomy will need to capture all aspects of the seismic performance and losses for an entire building, including building dimensions and non-structural components.
3. ***Distinguishes differences in seismic performance.*** The taxonomy distinguishes earthquake-resistant structural systems from non-earthquake resistant systems, including the "before" and "after" states of common seismic retrofits and between "ductile" and "non-ductile" systems.
4. ***Extensible***. All future data needs can't be foreseen, so the taxonomy will also have to lend itself to future extensions – i.e., be 'growable'. In the future, the GEM model may include other natural hazards such as floods, hurricanes and volcanic eruptions, and the taxonomy should be able to address those.
5. ***International in scope.*** As far as possible the taxonomy should be appropriate for any region of the world. It should not privilege any one region but be technically and culturally acceptable to all regions.
6. ***User-friendly.*** The taxonomy should be straightforward, intuitive, and as easy to use as possible by both those collecting data, those arranging for its analysis and the end users.

One of the challenges associated with the taxonomy development was the selection of key attributes which are required to describe building characteristics. The required number of attributes or the depth of information to be captured for a building depends on the specific use/application of the taxonomy, available data sources, and the type of data collection. The initial (Beta 0.1 version) of the taxonomy had approximately 60 attributes. A rather complete description of a unique building can be generated when all attributes are populated with data. However, the taxonomy was perceived as too detailed for intended purposes. The next version (V 1.0) had 8 basic attributes required by all GEM Risk components: i) material of the lateral load-resisting system, ii) lateral load-resisting system, iii) roof, iv) floor, v) height, vi) date of construction, vii) structural irregularity, and viii) occupancy. The current version V2.0 has 13 attributes. Five additional attributes were proposed as a result of the application of V1.0 taxonomy by the GEM researchers: direction, building position within a block, shape of the building plan, exterior walls, and foundation.

3 Vision for the GEM Building Taxonomy

The vision of the GEM Building Taxonomy team is to create a unique description (code) for a building or a building typology - something like a genetic code (genome), as shown in Figure 1. This *building genome* is defined by several attributes. Each attribute corresponds to a specific building characteristic that affects its seismic performance. Typical attributes include material, lateral load-resisting system, building height, etc. The proposed taxonomy scheme is flexible and provides an opportunity for adding and/or modifying attributes depending upon the level of detail required and a new knowledge gained through the data collection process; this is an advantage over alternative taxonomy models considering the global scope of GEM initiative. This taxonomy is different from majority of existing structural taxonomies used for seismic risk assessments and is seen as the Next Generation Taxonomy (NDT) by the Taxonomy team. The taxonomy data model is in line with modern Building Information Modelling (BIM) approaches and tools which are being used in construction industry.

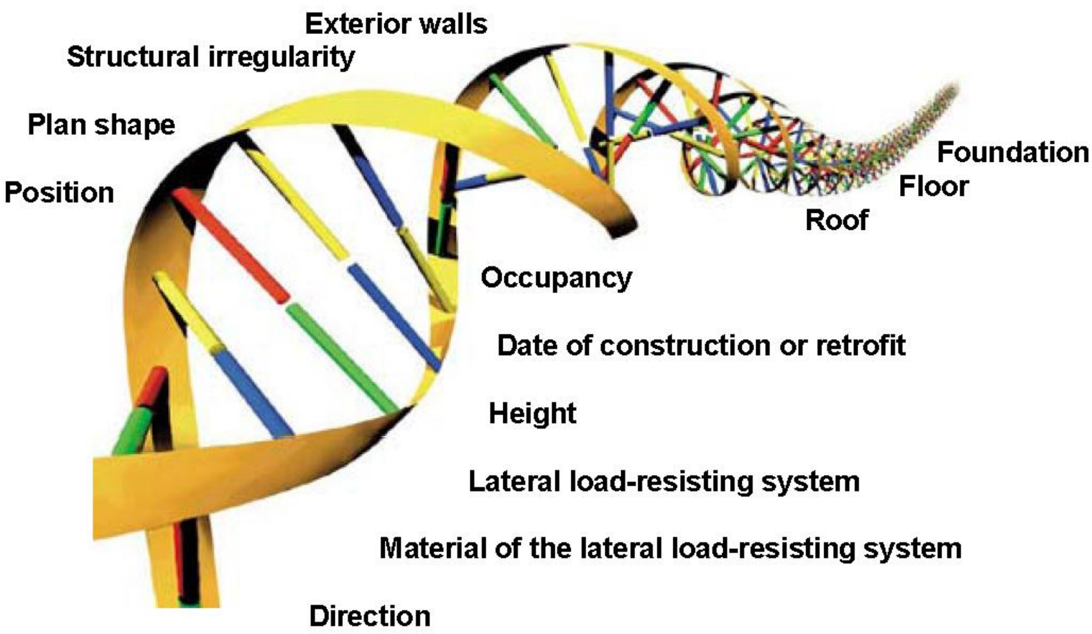

Figure 1. Building genome

4 Building Attributes

The GEM Building Taxonomy V2.0 describes a building or a building typology through the following 13 attributes which are associated with specific building characteristics that can potentially affect their seismic performance:

Direction - this attribute can be used to describe orientation of building(s) with different lateral load-resisting systems in two principal horizontal directions of the building plan which are perpendicular to one another

Material of the lateral load-resisting system - e.g. "masonry" or "wood"

Lateral load-resisting system - the structural system that provides resistance against horizontal earthquake forces through vertical and horizontal components, e.g. "wall", "moment frame", etc.

Height - building height above ground in terms of the number of storeys (e.g. a building is 3-storey high); this attribute also includes information on number of basements (if present) and the ground slope

Date of construction or retrofit - identifies the year when the building construction was completed

Occupancy - the type of activity (function) that the building is used for

Building position within a block - the position of a building within a block of buildings (e.g. "detached building" is not attached to any other building)

Shape of the building plan - e.g. L-shape, rectangular shape, etc.

Structural irregularity - a feature of a building's structural arrangement, such as one story significantly higher than other stories, an irregular building shape, or change of structural system or material, that produces a known vulnerability during an earthquake. Examples: re-entrant corner, soft storey, etc.

Exterior walls - material of exterior walls (building enclosure), e.g. "masonry", "glass", etc.

Roof - this attribute describes the roof shape, material of the roof covering, structural system supporting the roof covering, and roof-wall connection. For example, roof shape may be "pitched with gable ends", roof covering could be "tile", and roof system may be "wooden roof structure with light infill or covering".

Floor - describes floor material, floor system type, and floor-wall connection. For example, floor material may be "concrete", and the floor system may be "cast in-place beamless reinforced concrete slab".

Foundation - that part of construction where the base of the building meets the ground. The foundation transmits loads from the building to the underlying soil. For example, a shallow foundation supports walls and columns in a building for hard soil conditions, and a deep foundation needs to be provided for buildings located in soft soil areas.

The Taxonomy is organized as a series of expandable tables, which contain various attributes presented at several levels of detail. These tables are included in Appendix A of this report: Table G1 summarizes all attributes while Tables 1 to 13 contain detailed content for each attribute. Each attribute table contains several columns which include unique identifying characters/codes (IDs) in alphanumeric format, which are used to associate specific attribute details to the corresponding text descriptions. Each attribute can be described by one or more levels of details, which will be referred to as Level 1, 2, 3, etc., in this document. Attributes and associated details included in the GEM Building Taxonomy are presented in Figure 2.

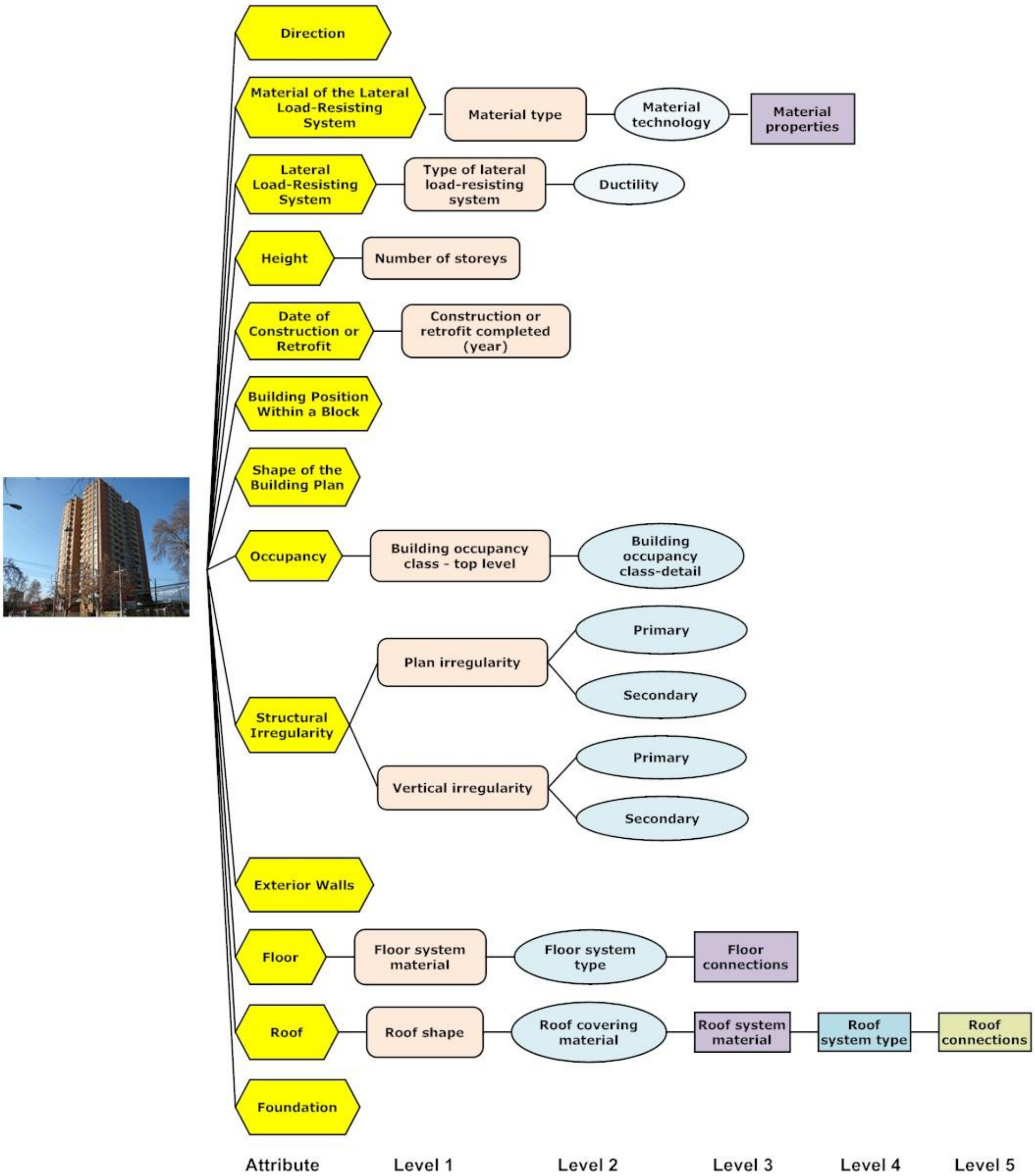

Figure 2. GEM Building Taxonomy: attributes and associated levels of detail

An example illustrating attributes and the associated levels of detail is presented in Figure 3. Material of the lateral load-resisting system is an attribute, and the details are presented in Table 2 of Appendix A. There are three levels of detail associated with the material, as follows:

1. Level 1 (L1): describes material type - a typical detail is CR and a corresponding description is "concrete, reinforced" (CR).
2. Level 2 (L2): further describes characteristics of L1 details - in this case the attribute level relates to Material Technology. For example, L1 detail CR (concrete, reinforced) can be associated with one of the following L2 details: CT99 (unknown concrete technology), CIP (cast-in-place concrete), PC (precast concrete), CIPPS (cast-in-place prestressed concrete), or PCPS (precast prestressed concrete).
3. Level 3 (L3): further describes the characteristics of the L2 details.

ID	Level 1 (L1) Material type	ID	Level 2 (L2) Material technology
MAT99	Unknown material		
C99	Concrete, unknown reinforcement		
CU	Concrete, Unreinforced		
CR	Concrete, Reinforced		
		CT99	Unknown concrete technology
		CIP	Cast-in-place concrete
		PC	Precast concrete
		CIPPS	Cast-in-place prestressed concrete
		PCPS	Precast prestressed concrete

Level 1

Level 2

Figure 3. An example of a Level 1 detail (CR = concrete, reinforced) and a Level 2 detail (e.g. CIP = cast-in-place concrete) (Source: Table 2, Appendix A)

The Direction attribute (Table 1 of Appendix A) enables the users to enter orientation of the lateral load-resisting system of a building and its material. It has been assumed that every building has two principal horizontal directions (X and Y) orthogonal (perpendicular) to one another. It is possible to specify different Lateral Load-Resisting Systems (LLRS) and the corresponding Material of the Lateral Load-Resisting System in Directions X and Y (see Figure 4).

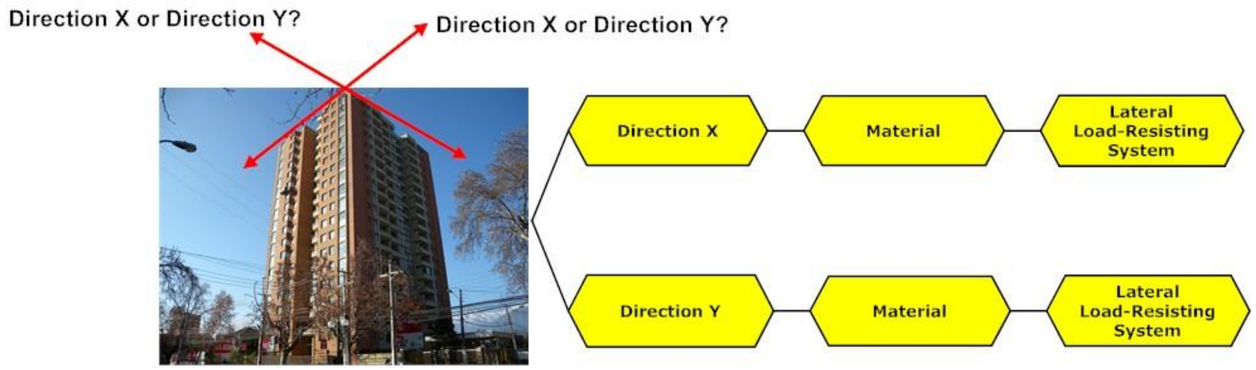

Figure 4. Direction attribute

Application of the Direction attribute will be explained on a building within a building block, with the main entrance facing the street, as shown in Figure 5. The building has two different LLRSs: reinforced concrete flat plate (slab and column system) parallel to street façade, and reinforced concrete wall system perpendicular to street façade. In this case, Direction X (parallel to street façade) is associated with a flat plate system (LFLS) (see Section 2), and Direction Y (perpendicular to street façade) is associated with a wall system (LWAL) (see Section 1).

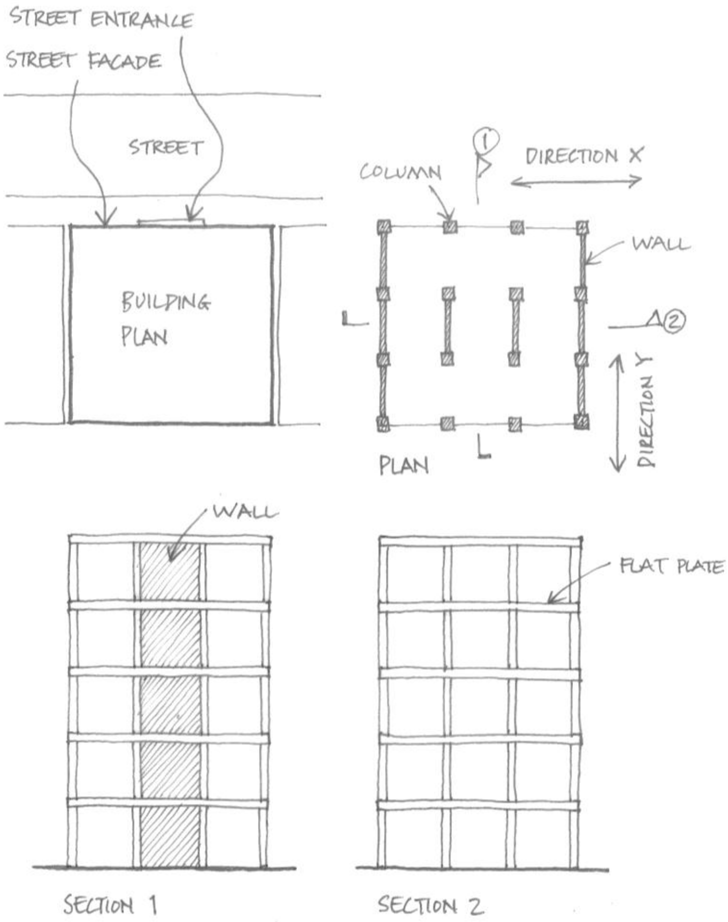

Figure 5. An application of the Direction attribute

In some cases it is difficult to specify principal directions for a building. An example is a building with circular plan shape shown in Figure 6. In that case, the user can choose Unspecified Direction (D99) to describe orientation of Directions X and Y.

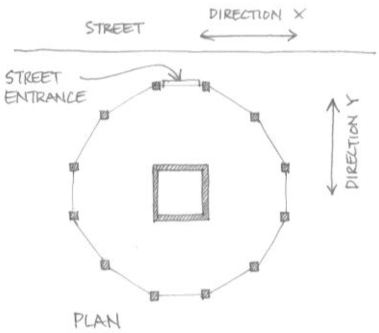

Figure 6. Direction attribute for a building with circular plan shape.

5 Applications and examples

The user can describe a building typology using the GEM Building Taxonomy in two ways: i) manually - by referring to the taxonomy tables included in Appendix A, or ii) by using a computer-based tool such as TaxT[7] where user can select attribute values and the process is facilitated through drop-down menus.

Once the user identifies all attributes/features of a building typology using the taxonomy tables, a taxonomy string can be created as a shorthand description of that typology. A taxonomy string can be compared to a bar code used to identify features of merchandise in stores. A mud hut with a thatch roof from an African country is shown in Figure 7.

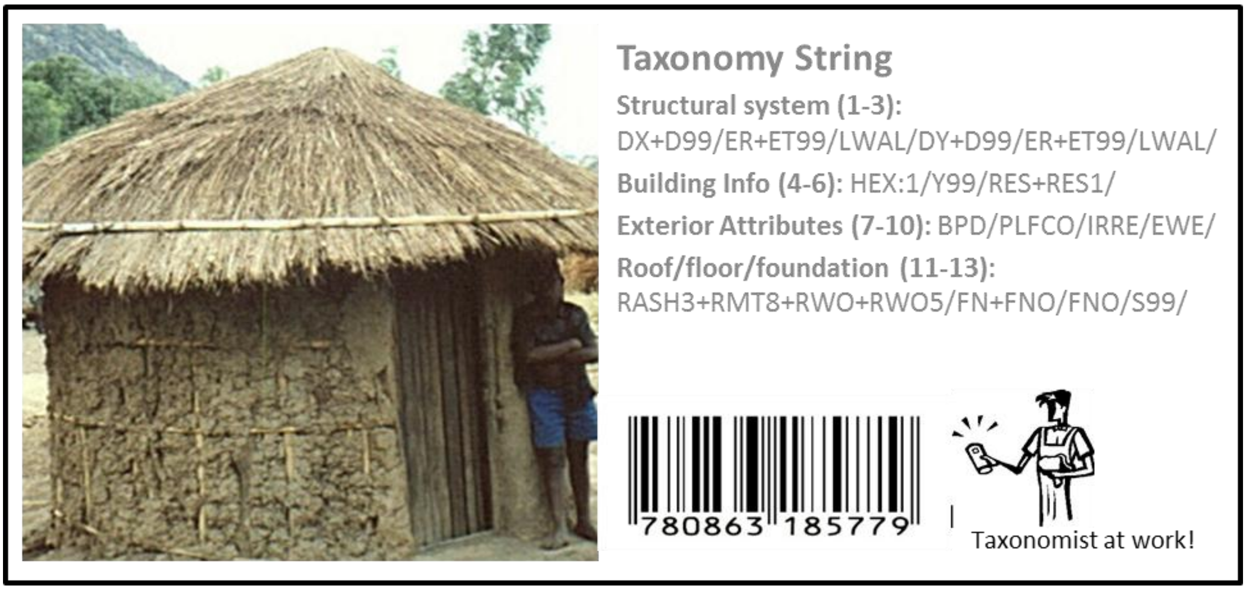

Figure 7. Taxonomy string is a bar code for a building. Photo: Rural Taxonomy mud wall building (Sassu and Ngoma, WHE Report 43).

The string represents a combination of unique IDs for selected attributes and attribute details and delimiters. Key rules associated with the creation of taxonomy strings are summarized below:

Attribute IDs:

Attributes need to be entered in the same sequence as presented in Table G1 of Appendix A.

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[7] Silva, V. (2012). TaxT - GEM Building Taxonomy Tester V.3.0

Each attribute value is defined by an identifier (ID) and the corresponding text description (see tables in Appendix A).

Attribute values which require numerical input (height and date of construction) are specified by a text ID, the colon sign “:”, and a number (integer).

Entries with unknown properties are labelled "99".

Delimiters:

Slash sign "/" is used to separate the attributes.

Plus sign "+" is used to include Level 2, Level 3, etc. attribute details with the Level 1 attribute.

Detailed rules are not included in this document since it is not expected that the participants in the evaluation and testing process are going to need to develop taxonomy strings manually. These rules were explained in the Version 1.0 GEM Building Taxonomy report, and will be included in the Version 2.0 GEM Building Taxonomy report.

It is expected that the GEM Building Taxonomy will be used to collect information on hundreds, if not thousands of building typologies found across the globe. Many of these building typologies have been classified by other global taxonomies, such as PAGER-STR (Jaiswal and Wald, 2008)[8]. GEM Building Taxonomy matches majority of building typologies included in the PAGER-STR taxonomy.

Applications of the GEM Building Taxonomy V 2.0 will be illustrated by a few examples. Note that the attributes for which information is not available are not discussed in examples and they are omitted from taxonomy strings.

EXAMPLE 1

A reinforced rubble stone masonry wall building with horizontal timber elements shown in Figure 8 is a type of construction found in South-East Asia (India, Nepal, and Pakistan), Turkey, Greece, etc.

[8] Jaiswal, K.S., and Wald, D.J. (2008). Creating a Global Building Inventory for Earthquake Loss Assessment and Risk Management, U.S. Geological Survey Open-File Report 2008-1160, 103 p. <http://earthquake.usgs.gov/earthquakes/pager/>

Figure 8. Reinforced rubble stone masonry with horizontal timber elements, Pakistan (Bothara and Brzev, 2011[9])

This building typology can be described in several ways. Three different options are described below.

Option 1: direct coding

Direct "coding" of the description "a reinforced rubble stone masonry building with horizontal timber elements" can be described by the following string:

/MR+RW+STRUB/LWAL/

Where MR - a Level 1 detail for the Material attribute with the description "Masonry, Reinforced" (see Table 2 of Appendix A),

STRUB - denotes rubble stone masonry, a Level 2 detail associated with the Masonry Level 1 details (see Table 2 of Appendix A),

RW - denotes timber-reinforced masonry, a Level 2 detail associated with the "Masonry, Reinforced" (see Table 2 of Appendix A), and

LWAL - denotes that the lateral load-resisting system is a shear wall (see Table 3, Appendix A).

Option 2: a more detailed description

A user familiar with this type of stone masonry construction would likely assume that buildings of this type are usually built using mud mortar. Therefore, (s)he could specify type of mortar (MOM in this case) as a Level 3 detail.

/MR+RW+STRUB+MOM/LWAL/

Note that the Level 3 detail (MOM), shown underlined in the above string, is associated with the Level 2 detail (STRUB). Alternatively, the user could specify the type of stone as Level 3 detail, but in that case it is not possible to specify type of mortar. For example, if granite stone boulders are used (SPGR in Table 2, Level 3 detail for masonry), the taxonomy string is as follows:

/MR+RW+STRUB+SPGR/LWAL/

Option 3: least detailed (aggregated) description

A user with limited expertise associated with building construction practices and/or less information available related to the same building class could define this as "a masonry building". This implies that resistance to lateral seismic forces is provided by walls. The following string could be used to describe this building:

/M99/LWAL/

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[9] Bothara,J. and Brzev,S. (2011). A Tutorial: Improving the Seismic Performance of Stone Masonry Building, World Housing Encyclopedia, Earthquake Engineering Research Institute, Oakland, California

where M99 refers to "Masonry, unknown reinforcement" in Table 2. This represents an example of low-detail (aggregated) building typology description.

EXAMPLE 2

Another example of a building typology is related to older unreinforced masonry buildings from the beginning of the 20th century common in many European countries. A typical building is shown in Figure 9 (the photo was taken in Ljubljana, Slovenia). The typology description was provided by the GEMECD group, and it is taken from the Earthquake Consequences Database which is currently under development (Lee, Pomonis, So, and Spence, 2011[10]). Two different records/strings have been created (Record A and Record B), depending on the available information, as illustrated in Figure 9.

Record A describes the typology in an aggregated form, assuming that only general information is available. Only a few basic attributes are used for this record, and the level of detail is low, that is, information on Level 2 and Level 3 attribute details is not available. For example, some users would not be able to determine which type of masonry units were used in this building (because the exterior walls are overlaid with plaster).

Record B describes the same building typology in more detail, but within the structure available in the Building Taxonomy. All attributes have been used in this case. Users familiar with regional construction practices would be able to determine that the masonry walls were not reinforced (MUR is a Level 1 detail in Table 2 of Appendix A), and that fired clay solid bricks were used for wall construction (CLBRS is a Level 2 detail in Table 2). For buildings in that region of Europe built before World War II, cement:lime mortar was used for masonry construction (MOCL is a Level 3 detail in Table 2). The user can refer to the Building Taxonomy Glossary descriptions for mortar terms if in doubt, since there is an option to use either low-strength or regular strength mortar. Lime and cement mortar is identified as regular strength mortar per the Glossary document. The user could also provide more information about roof system. It is likely that wood trusses were used as a roof system. It is obvious that roof is pitched and that clay tiles were used as roof covering. Wooden floor system was likely used.

Finally, since the building was built before World War II, which started in 1939, the user should specify YPRE (latest date prior to the date of construction) as 1939 (see Table 5 in Appendix A), that is, YPRE:1939. However, if the user happens to know that the building was retrofitted in the 1990s, that is, before 2000, the taxonomy description should be YPRE:2000. It is believed that, if a building was retrofitted, the information related to the retrofit (including lateral load-resisting system and date of retrofit) is more important than the information related to the original construction. When the year of retrofit is known, the user can track the vintage of the building code that was likely used to design the retrofit solution.

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[10] Lee,W.,V., Pomonis,A., So,E., and Spence,R. (2011). Existing Building Stock Classification in the Cambridge Earthquake Impact Database (CEQID). GEM Technical Report 2011, GEM Foundation, Pavia, Italy.

1. Load bearing masonry, mostly residential, built before the World War II

References from other structural taxonomies:
PAGER-STR (UFB, UFB3, UFB4)   EERI WHE (7,8)   EMS-98 (M5)

Description

Residential buildings found in several European countries (Italy, Greece, Hungary, former Yugoslavia, etc.). By and large, these buildings were built at the beginning of the 20th century before World War II. The main gravity and lateral load resisting systems consist of unreinforced masonry walls, usually built using fired clay bricks in cement:lime mortar. The walls are usually plastered. These buildings usually have wood floors, and clay tile roofing covering a sloped wood roof.

RECORD A: Basic information available (aggregated record)

Direction (Table 1)	*Material (Table 2)*	*Lateral Load-Resisting System (Table 3)*	*Height (Table 4)*	*Date of construction or retrofit (Table 5)*	*Occupancy (Table 6)*	*Structural Irregularity (Table 9)*	*Roof system (Table 11)*	*Floor system (Table 12)*
Unspecified **D99**	Masonry, unreinforced (not sure of exact type - brick or block due to plaster) **MUR**	Wall **LWAL**	Exactly two-storey high **HEX:2**		Residential, unknown type **RES+RES99**		Roof shape: pitched and hipped Roof covering: unknown Roof system material: wood Roof system: unknown **RSH3+RMT99+RWO+RWO99**	

DX:D99/MUR/LWAL/DY:D99/MUR/LWAL/HEX:2//RES+RES99///// RSH3+RMT99+RWO+RWO99///

RECORD B: Detailed information available (when the user is more familiar with the regional construction practices, and the exact year of construction)

Direction (Table 1)	*Material (Table 2)*	*Lateral Load-Resisting System (Table 3)*	*Height (Table 4)*	*Date of construction or retrofit (Table 5)*	*Occupancy (Table 6)*	*Structural Irregularity (Table 9)*	*Roof system (Table 11)*	*Floor system (Table 12)*
Unspecified **D99**	Unreinforced Masonry+solid fired clay bricks+cement:lime mortar **MUR+CLBRS +MOCL**	Wall **LWAL**	Exactly two-storey high **HEX:2**	Built before World War II (before 1939) **YPRE:1939**	Residential, unknown type **RES+RES99**	Regular structure **IRRE**	Roof shape: pitched and hipped Roof covering: clay tiles Roof system material: wood Roof system type: wood trusses **RSH3+RMT1 + RWO+RWO2**	Wood, unknown **FW+FW99**

DX:D99/ MUR+CLBRS+MOCL /LWAL/DY:D99/ MUR+CLBRS+MOCL /LWAL /HEX:2//RES+RES99///IRRE// RSH3+RMT99+RWO+RWO99 /FW+FW99//

Figure 9. An example of a building typology description using the GEM Building Taxonomy

EXAMPLE 3: A building with two different Lateral Load-Resisting Systems in two principal horizontal directions

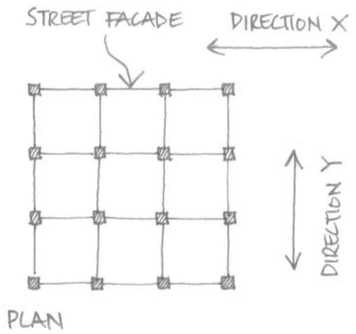
For example, the user would like to describe a reinforced concrete building with two different lateral load-resisting systems shown in Figure 10. Direction X parallel to street façade is characterized by cast in-place reinforced concrete moment frame, and Direction Y is characterized by cast-in-place reinforced concrete wall system. Direction Y is perpendicular to Direction X. The taxonomy string for attributes 1 to 3 is as follows:

/DX+PF/CR+CIP/LFLS/DY+OF/CR+CIP/LWAL/

Example 4: A building with the same lateral load-resisting system in both directions

Consider a building plan where both directions (DX and DY) are characterized by reinforced concrete moment frame (LFM). The taxonomy string for attributes 1 to 3 is as follows:

/DX+PF/CR+CIP/LFM/DY+OF/ CR+CIP/LFM/



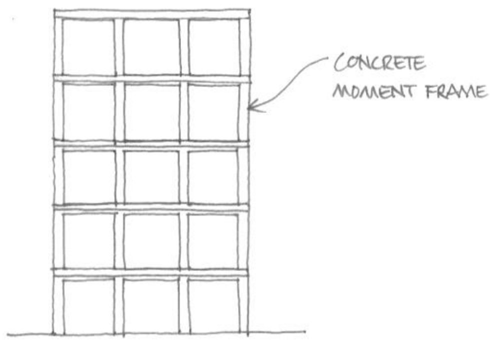


Figure 10. A building with the same lateral load-resisting system in both directions

Example 5: Building with multiple entrances

Consider the building plan with the same LLRS as Example 3 shown in Figure 11. The building is a part of a residential development (building complex) and it has more than one main entrance. In this case, Direction X and Direction Y cannot be associated with street (main) façade. However, it is still possible to record two different LLRSs in two principal directions by using the attribute value Direction Unspecified (D99) for both directions. The taxonomy string for attributes 1 to 3 is as follows:

/DX+D99/CR+CIP/LFLS/DY+D99/CR+CIP/LWAL/

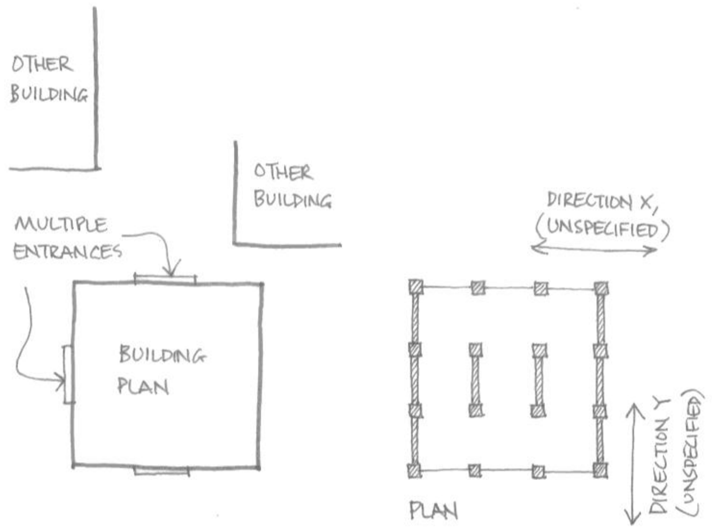


Figure 11. An example of a building with unspecified directions

EXAMPLE 6: A building with structural irregularities

a) The building has principal and secondary irregularities in both directions

Let us consider an example where a building has two plan irregularities: torsion eccentricity (TOR) as primary irregularity and re-entrant corner (REC) as secondary irregularity. There are also two irregularities in vertical direction: soft storey (SOS) as primary irregularity and pounding potential (POP) as secondary irregularity. The resulting taxonomy string is as follows:

/IR+IRPP:TOR+IRPS:REC+IRVP:SOS+IRVS:POP/

b) The building has one irregularity in plan and vertical direction each

Consider the same building, but include only information about primary irregularities for plan and vertical directions. The taxonomy string is as follows:

/IR+IRPP:TOR+IRPS:IRN+IRVP:SOS+IRVS:IRN/

In this case, the ID IRN (no irregularity) should be assigned to both secondary plan irregularity (IRPS) and secondary vertical irregularity (IRVS).

c) The building has only plan irregularities

Consider the same building, but include only information about plan irregularities. The taxonomy string is as follows:

/IR+IRPP:TOR+IRPS:REC+IRVP:IRN+IRVS:IRN/

In this case, the ID IRN (no irregularity) should be assigned to vertical irregularities.

d) The building has only vertical irregularities

Consider the same building, but include only information about vertical irregularities. The taxonomy string is as follows:

/IR+IRPP:IRN+IRPS:IRN+IRVP:SOS+IRVS:POP/

In this case, the ID IRN (no irregularity) should be assigned to plan irregularities.

EXAMPLE 5: Mapping to PAGER-STR Taxonomy

A user desires to describe light timber frame construction (wood-stud frame), a common housing practice in North America shown in Figure 12. This corresponds to typology W1 in the PAGER-STR taxonomy[11], according to the following description:

> *Wood stud-wall frame with plywood/gypsum board sheathing. Absence of masonry infill walls. Shear wall system consists of plywood or manufactured wood panels. Exterior is commonly cement plaster ("stucco"), wood or vinyl planks, or aluminium planks (in lower cost houses). In addition, brick masonry or stone is sometimes applied to the exterior as a non-load-bearing veneer. The roof and floor act as diaphragms to resist lateral loading. (US & Canadian single family homes).*

This building typology can be described in the GEM shorthand form as follows:

/W+WLI/LWAL/RWO+RWO3/

Where W - denotes Wood (Level 1 Material), WLI - light wood members (Level 2 detail associated with W), LWAL - wall system (since wood-stud frame can be treated as an equivalent wall for lateral load purpose), RWO - wooden roof, and RWO3 - wood-based sheets on rafters and purlins (this is a roof type associated with RWO).

Figure 12. Light timber frame construction, USA (Arnold, WHE Report 65[12])

A Microsoft® Excel document showing mapping of PAGER-STR taxonomy and GEM Building Taxonomy is posted on the GEM NEXUS platform[13].

[11] http://pager.world-housing.net/data-available/construction-types
[12] Arnold, C. Wood Frame Single Family House, World Housing Encyclopedia, Report 65, www.world-housing.net
[13] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/posts/updated-gem-basic-building-taxonomy-v1.0

6 GEM Building Taxonomy Tester (TaxT)

It is expected that the Taxonomy will be mostly used in computer applications. TaxT is a computer application developed by GEM researcher Vitor Silva (Portugal). TaxT enables a user to record information about a building or a building typology using 13 attributes of the GEM Building Taxonomy V2.0 divided into four groups, as shown in Table G1 in Appendix A: structural system (attributes 1 to 3), building information (4 to 6), exterior attributes (7 to 10), and roof/floor/foundation (11 to 13). Screen display of TaxT is shown in Figure 13. TaxT also generates a taxonomy string corresponding to the information entered by the user for each building typology. In addition, TaxT enables users to generate a report in PDF format which summarizes attribute values (s)he has chosen as representative of the building typology under consideration. The report may also include a photo of the building typology, and a text box where comments can be entered.

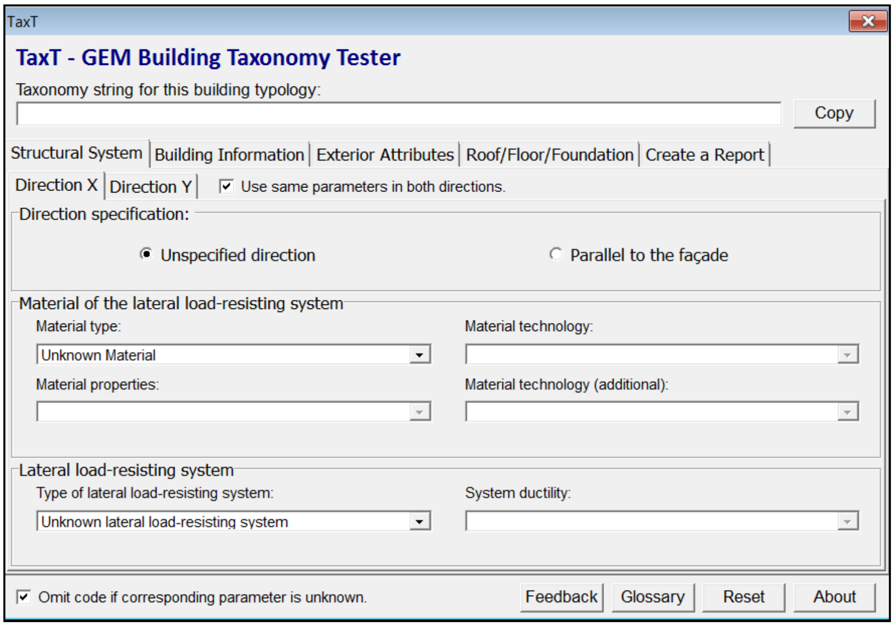


Figure 13. TaxT building taxonomy tester - a computer application

7 Glossary

All relevant terms in the GEM Building Taxonomy have been explained in a companion document titled *Glossary for the GEM Building Taxonomy* which is published in the NEXUS website[1] www.nexus.globalquakemodel.org/gem-building-taxonomy/posts/glossary-for-the-building-taxonomy. The Glossary comprises hundreds of terms containing text description and illustrations (photographs and drawings) associated with the taxonomy terms. Members of the GEM community can review the glossary, suggest improvements and contribute photographs related to various terms.

Two sample glossary terms are presented below. The first term describes a Post and Beam lateral load resisting system (LPB in Table 2 of Appendix A).

Post and beam

A framework of posts and beams where posts are spaced several metres apart. If the posts do not cantilever from the foundations, lateral stability may be supplemented by infill walls or by small diagonal bracing members at post and beam connections that provide some rigidity against horizontal forces. Includes systems comprised of posts and trusses with simple pin-jointed connections between them. If most of the seismic resistance is provided by infill walls then the lateral load-resisting system should be described as wall.

Note that posts and beams include vertically cantilevered posts or columns without rigidly connected beams that would otherwise transform this structural system into a moment frame. If these vertical members have a height to depth or length (measured in the direction they resist horizontal load) less than 3.0 they should be considered as walls.

Synonyms: Trabeated Construction, Post and Lintel, or Column and Beam.


The second term describes precast concrete construction (PC), which is a Level 2 attribute value in Table 1, associated with the Level 1 attribute "Concrete, Reinforced" (CR).

Precast concrete

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

APPENDIX A Table G1: GEM Building Taxonomy: Attributes

Attribute Group	#	Attribute	Reference	Attribute levels	Type	Example
Structural System	1	Direction	Table 1	Direction of the building		
	2	Material of the Lateral Load-Resisting System	Table 2	Material type (Level 1)	Text	Steel
				Material technology (Level 2)		
				Material properties (Level 3)		
	3	Lateral Load-Resisting System	Table 3	Type of lateral load-resisting system (Level 1)	Text	Braced frame
				System ductility (Level 2)		
Building Information	4	Height	Table 4	Number of storeys	Integer	4
	5	Date of Construction or	Table 6	Construction completed (year)	Integer	1925
	6	Occupancy	Table 5	Building occupancy class - general (Level	Text	Residential
				Building occupancy class - detail (Level 2)		
Exterior Attributes	7	Building Position within a	Table 7		Text	
	8	Shape of the Building Plan	Table 8	Plan shape (footprint)	Text	
	9	Structural Irregularity	Table 9	Regular or irregular (Level 1)	Text	Re-entrant corner
				Plan irregularity or vertical irregularity		
				Type of irregularity (Level 3)		
	10	Exterior Walls	Table 10	Material of exterior walls	Text	Wood

Roof/Floor/ Foundation	11	Roof	Table 12	Roof shape (Level 1)	Text	Tile (clay, concrete)
				Roof covering material (Level 2)		
				Roof system material (Level 3)		
				Roof system type (Level 4)		
				Roof connections (Level 5)		
	12	Floor	Table 11	Floor system material (Level 1)	Text	Concrete
				Floor system type (Level 2)		
				Floor connections (Level 3)		
	13	Foundation	Table 13	Foundation system	Text	Shallow foundation, with lateral

Table 1: Direction

ID	Level 1 (L1)	ID	Level 2 (L2)	
	Direction of building under consideration		**Description of the direction**	**Definition**
	Direction X			First principal horizontal direction of the building plan. This direction is orthogonal to Direction Y.
		D99	Unspecified direction	The direction is not known. Example: street survey of buildings which don't have a distinguishable street façade or main entrance, including circular or curved buildings
		PF	Parallel to the main façade	The direction parallel to the façade associated with the street address or the main entrance
	Direction Y			Second principal horizontal direction of the building plan. This direction is orthogonal to Direction X.
		D99	Unspecified direction	The direction is not known. Example: street survey of buildings which don't have a distinguishable street façade or main entrance, including circular or curved buildings
		OF	Perpendicular to the main façade	The direction perpendicular (orthogonal) to the façade associated with the street address or the main entrance

Comment: This attribute is provided to enable the users to enter information about the lateral load-resisting system of a building and its material. Every building has two principal horizontal directions orthogonal (perpendicular) to one another, and it is possible that a building is characterized by different lateral load-resisting systems in these two directions. The terms Direction X and Direction Y are used to overcome difficulties associated with attempts to identify longitudinal and transverse direction of a building. Instead, the directions are related to the orientation of the main façade, usually facing street (also known as street façade).

Table 2: Material of the Lateral Load-Resisting System

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
Attribute_Type_Code	**MAT_TYPE**		**MAT_TECH**		
MAT99	Unknown material				
C99	Concrete, unknown reinforcement	CT99	Unknown concrete technology		
CU	Concrete, unreinforced	CIP	Cast-in-place concrete		
CR	Concrete, reinforced	PC	Precast concrete		
SRC	Concrete, composite with steel section	CIPPS	Cast-in-place prestressed concrete		
		PCPS	Precast prestressed concrete		
S	Steel			**STEEL_CONN**	
		S99	Steel, unknown	SC99	Steel connections, unknown
		SL	Cold-formed steel members	WEL	Welded connections
		SR	Hot-rolled steel members	RIV	Riveted connections
		SO	Steel, other	BOL	Bolted connections
ME	Metal (except steel)				
		ME99	Metal, unknown		
		MEIR	Iron		
		MEO	Metal, other		
Attribute_Type_Code	**MAT_TYPE**		**MAT_TECH**		
				MAS_MORT	
M99	Masonry, unknown reinforcement	MUN99	Masonry unit, unknown	MO99	Mortar type unknown
MUR	Masonry, unreinforced	ADO	Adobe blocks	MON	No mortar

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
MCF	Masonry, confined	ST99	Stone, unknown technology	MOM	Mud mortar
MR	Masonry, reinforced	STRUB	Rubble (field stone) or semi-dressed stone	MOL	Lime mortar
		STDRE	Dressed stone	MOC	Cement mortar
		CL99	Fired clay unit, unknown type	MOCL	Cement:lime mortar
		CLBRS	Fired clay solid bricks	SP99	Stone, unknown type
		CLBRH	Fired clay hollow bricks	SPLI	Limestone
		CLBLH	Fired clay hollow blocks or tiles	SPSA	Sandstone
		CB99	Concrete blocks, unknown type	SPTU	Tuff
		CBS	Concrete blocks, solid	SPSL	Slate
		CBH	Concrete blocks, hollow	SPGR	Granite
		MO	Masonry unit, other	SPBA	Basalt
		MASS_REIN		SPO	Stone, other type
		MR99	Masonry reinforcement, unknown		
		RS	Steel-reinforced		
		RW	Wood-reinforced		
		RB	Bamboo-, cane- or rope-reinforced		
		RCM	Reinforced composite mesh		
		RCB	Reinforced concrete bands		

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
Attribute_Type_Code	**MAT_TYPE**		**MAT_TECH**		
E99	Earth, unknown reinforcement	ET99	Unknown earth technology		
EU	Earth, unreinforced	ETR	Rammed earth		
ER	Earth, reinforced	ETC	Cob or wet construction		
		ETO	Earth technology, other		
W	Wood				
		W99	Wood, unknown		
		WHE	Heavy wood		
		WLI	Light wood members		
		WS	Solid wood		
		WWD	Wattle and daub		
		WBB	Bamboo		
		WO	Wood, other		
MATO	Other material				

Table 3: Lateral Load-Resisting System

ID	Level 1 (L2)	ID	Level 2 (L2)
	Type of lateral load-resisting system		**System ductility**
Attribute_Type_Code	**LLRS**		**LLRS_DUCT**
L99	Unknown lateral load-resisting system	D99	Ductility unknown
LN	No lateral load-resisting system	DUC	Ductile
LFM	Moment frame	DNO	Non-ductile
LFINF	Infilled frame	DBD	Equipped with energy dissipation devices
LFBR	Braced frame		
LPB	Post and beam		
LWAL	Wall		
LDUAL	Dual frame-wall system		
LFLS	Flat slab/plate or waffle slab		
LFLSINF	Infilled flat slab/plate or infilled waffle slab		
LH	Hybrid lateral load-resisting system		
LO	Other lateral load-resisting system		

Table 4: Height

ID	Level 1 (L1)	ID		Definition	Examples
	Number of storeys				
Attribute_Type_Code					
H99	Number of storeys unknown				
Attribute_Type_Code	**STORY_AG**				
H	Number of storeys above ground				
		HBET	Range of number of storeys above ground	HBET:a,b = range of number of storeys (a=upper bound and b= lower bound) The range reflects either surveyor's lack of certainty for a single building, or it is applicable to height ranges used in regional surveys	Range HBET:3,1 (height range from 1 to 3 storeys)
		HEX	Exact number of storeys above ground	HEX:n = maximum number of storeys above ground level	Fixed number (integer) HEX:2 (two storeys)
		HAPP	Approximate number of storeys above ground	HAPP:n = approximate number of storeys above ground level	Fixed number (integer) HAPP:2 (two storeys)
Attribute_Type_Code	**STORY_BG**				
HB	Number of storeys below ground			Number of storeys below the level of the primary entrance	

				(same as number of basements)	
		HB99	Number of storeys below ground unknown		
		HBBET	Range of number of storeys below ground		Range (meters) HBBET: 3,1 (between 1 and 3 levels of basement)
		HBEX	Exact number of storeys below ground		Fixed number (integer) e.g. HBEX:2 (two levels of basement)
		HBAPP	Approximate number of storeys below ground		
Attribute_Type_Code	**HT_GR_GF**				
HF	Height of grade above ground level			Grade is usually somewhat lower than the ground level (this information is relevant for flood hazard and foundation seismic performance)	
		HF99	Height of grade unknown		
		HFBET	Range of height of grade above ground level	HFBET:a,b (a= upper bound and b=lower bound)	Range (meters) HFBET: 1.0,0.5 (between 0.5 m and 1.0 m)
		HFEX	Exact height of grade above ground level		HFEX:0.75 (exactly 0.75 m)
		HFAPP	Approximate height of grade above ground level		HFAPP:0.5 (approximately 0.5 m)

x

Attribute_Type_Code	**SLOPE**				
		HD99	Slope of the ground unknown		
	Slope of the ground	HD	Slope of the ground (for buildings on slopes)	HD:a	Integer (degrees) e.g. HD :10 (10 degrees)

Table 5: Date of Construction or Retrofit

ID	Level 1 (L1)	Definition	Examples
	Date of construction		
Attribute_Type_Code	**YR_BUILT**		
Y99	Year unknown		
YEX	Exact date of construction or retrofit	Year during which the construction was completed or retrofitted.	YEX:1936
YBET	Upper and lower bound for the date of construction or retrofit	The construction likely took place between 1930 and 1940.	YBET:1940,1930
YPRE	Latest date preceding the date of construction or retrofit	The construction was completed before the World War II, thus the year entered is 1939.	YPRE:1939
YAPP	Approximate date of construction or retrofit	The construction was completed approximately in 1935	YAPP:1935

Note: There is a possibility of entering information related either to the date of original construction or the retrofit - whichever occurs later. For example, if a building was constructed in 1936 and it was retrofitted in 1991, the user should enter 1991.

Table 6: Occupancy[14]

ID	Level 1 (L1)		ID	Level 2 (L2)	
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**	**Definition**
Attribute_Type_Code	**OCCUPCY**			**OCCUPCY_DT**	
OC99	Unknown occupancy type				
RES	Residential				
			RES99	Residential, unknown type	
			RES1	Single dwelling	This includes various dwelling sizes, from a small home to a castle
			RES2	Multi-unit, unknown type	
			RES2A	2 Units (duplex)	
			RES2B	3-4 Units	
			RES2C	5-9 Units	
			RES2D	10-19 Units	
			RES2E	20-49 Units	

[14] Adapted from Multi-hazard Loss Estimation Methodology, Earthquake Model, HAZUS®MH Technical Manual, National Institute of Building Sciences and Federal Emergency Management Agency, Washington, DC, 2003, 690 pp.

ID	Level 1 (L1)		ID	Level 2 (L2)	
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**	**Definition**
			RES2F	50+ Units	
			RES3	Temporary lodging	
			RES4	Institutional housing	
			RES5	Mobile home	
COM	Commercial and public				
			COM99	Commercial and public, unknown type	
			COM1	Retail trade	
			COM2	Wholesale trade and storage (warehouse)	
Attribute_Type_Code	**OCCUPCY**			**OCCUPCY_DT**	
			COM3	Offices, professional/technical services	
			COM4	Hospital/medical clinic	
			COM5	Entertainment	Restaurants, bars, cafes
			COM6	Public building	
			COM7	Covered parking garage	
			COM8	Bus station	
			COM9	Railway station	
			COM10	Airport	

ID	Level 1 (L1)		ID	Level 2 (L2)	
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**	**Definition**
			COM11	Recreation and leisure	Smaller sport facilities, leisure centres
MIX	Mixed use				
			MIX99	Mixed, unknown type	
			MIX1	Mostly residential and commercial	
			MIX2	Mostly commercial and residential	
			MIX3	Mostly commercial and industrial	
			MIX4	Mostly residential and industrial	
			MIX5	Mostly industrial and commercial	
			MIX6	Mostly industrial and residential	
IND	Industrial				
			IND99	Industrial, unknown type	
			IND1	Heavy industrial	
			IND2	Light industrial	
AGR	Agriculture				
			AGR99	Agriculture, unknown type	
			AGR1	Produce storage	It includes grain storage, and also hay, silage, fruit, vegetables, etc.
			AGR2	Animal shelter	Example: shelter for cows during the winter, but it may not necessarily have to do with

ID	Level 1 (L1)		ID	Level 2 (L2)	
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**	**Definition**
					the rearing.
			AGR3	Agricultural processing	This includes abatoirs
ASS	Assembly				
			ASS99	Assembly, unknown type	
			ASS1	Religious gathering	
			ASS2	Arena	
			ASS3	Cinema or concert hall	
			ASS4	Other gatherings	Clubs, societies, political parties, function centres, etc.
GOV	Government				
			GOV99	Government, unknown type	
			GOV1	Government, general services	
			GOV2	Government, emergency response	
EDU	Education				
			EDU99	Education, unknown type	
			EDU1	Pre-school facility	
			EDU2	School	
			EDU3	College/university, offices and/or classrooms	
			EDU4	College/university, research facilities and/or labs	

ID	Level 1 (L1)		ID	Level 2 (L2)	
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**	**Definition**
OCO	Other occupancy type				

Table 7: Building Position within a Block

ID	Level 1 (L1)	Definition	Examples
BP	**Building Position within the Block**		
Attribute_Type_Code	**POSITION**		
BPD	Detached building	Not attached to any other building (free); this applies to buildings that are spaced apart a distance equal to or more than 4% of the height of the lower building	
BP1	One adjacent building	One adjacent building (semi-detached building in North America), e.g. end of a row	
BPC	Corner building	Corner building with two adjacent buildings (on adjacent sides)	
BP3	Three adjacent buildings		
BPI	Interior of block	Building within a block with two adjacent buildings (on opposite sides)	

Table 8: Shape of the Building Plan

ID	Level 1 (L1)
PLF	**Footprint (plan shape)**
Attribute_Type_Code	**PLAN_SHAPE**
PLF99	Unlisted footprint shape
PLFSQ	Square, solid
PLFSQO	Square, with an interior opening (e.g. a "donut")
PLFR	Rectangular, solid
PLFRO	Rectangular, with an opening
PLFL	L-shape
PLFA	A-shape
PLFB	B-shape
PLFC	Curved, solid (e.g. circular, elliptical, ovoid)
PLFCO	Circular, with an opening
PLFD	Triangular shape, solid
PLFDO	Triangular shape, with an opening
PLFE	E-shape
PLFF	F-shape
PLFH	H-shape
PLFS	S-shape
PLFT	T-shape
PLFU	U-shape
PLFX	X-shape
PLFY	Y-shape
PLFI	Irregular

Footprint = Projection of the exterior edge of the building at grade onto the horizontal plane.

Table 9: Structural Irregularity

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Regular or irregular		**Plan irregularity or vertical irregularity**		**Type of irregularity**
Attribute_Type_ Code	**STR_IRREG**				
IR99	Unknown structural irregularity				
IRRE	Regular structure				
IRIR	Irregular structure				
		Attribute_Type_ Code	**STR_HZIR_P**		
		IRPP	Plan irregularity-primary	IRN	No irregularity
				TOR	Torsion eccentricity
				REC	Re-entrant corner
				OFS	Offset structure
				IRHO	Other horizontal irregularity
		Attribute_Type_ Code	**STR_HZIR_S**		
		IRPS	Plan irregularity-secondary	IRN	No irregularity
				TOR	Torsion eccentricity
				REC	Re-entrant corner
				OFS	Offset structure
				IRHO	Other horizontal irregularity

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Regular or irregular		**Plan irregularity or vertical irregularity**		**Type of irregularity**
		Attribute_Type_Code	**STR_VEIR_P**		
		IRVP	Vertical structural irregularity - primary	IRN	No irregularity
				SOS	Soft storey
				CRW	Cripple wall
				SHC	Short column
				POP	Pounding potential
				SET	Setback
				CHV	Change in vertical structure (includes large overhangs)
				IRVO	Other vertical irregularity
		Attribute_Type_Code	**STR_VEIR_S**		
		IRVS	Vertical structural irregularity - secondary	IRN	No irregularity
				SOS	Soft storey
				CRW	Cripple wall
				SHC	Short column
				POP	Pounding potential
				SET	Setback

				CHV	Change in vertical structure (includes large overhangs)
				IRVO	Other vertical irregularity

Comment: This table has been updated to reflect the data model used by GEM Risk groups. A building can be characterized by primary and secondary plan and vertical irregularity. It is also possible for a building to have plan irregularities and vertical irregularities.

Table 10: Exterior Walls

ID	Level 1 (L1)	
EW	**Material of exterior walls**	**Description: material that covers most of the wall area**
Attribute_Type_Code	**NONSTRCEXW**	
EW99	Unknown material	
EWC	Concrete	Cast in-place or precast concrete panels
EWG	Glass	Glass curtain walls, storefront glass systems
EWE	Earth	Adobe, cob, rammed earth, bajareque, quincha, sod, banco, etc.
EWMA	Masonry	Various masonry units (clay bricks/blocks/stone/ceramic tile) in the form of veneers, cavity walls, infill walls
EWME	Metal	Aluminum planks, corrugated iron or steel sheets (CGI)
EWV	Vegetative	Matting, palm, thatch, straw, etc.
EWW	Wood	Wood planks, wood shingles
EWSL	Stucco finish on light framing	Metal or wood studs with wood or insulated underlay
EWPL	Plastic/vinyl, various	Plastic siding; plastic sheet
EWCB	Cement-based boards	Fibre cement or asbestos boards, e.g. GRC, FRC
EWO	Material of exterior wall, other	

Table 11: Roof

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
RSH	**Roof shape**	**RMT**	**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
Attribute_Type_Code	**ROOF_SHAPE**		**ROOFCOVMAT**		**ROOFSYSMAT**		**ROOFSYSTYP**		**ROOF_CONN**
RSH99	Unknown roof shape	RMT99	Unknown roof covering	R99	Roof material, unknown			RWC99	Roof-wall diaphragm connection unknown
RSH1	Flat	RMN	No roof covering (roof system exposed)					RWCN	Roof-wall diaphragm connection not provided
RSH2	Pitched with gable ends	RMT1	Tile (clay, concrete)	RM	Masonry			RWCP	Roof-wall diaphragm connection present (the connection transfers in-plane forces from floor to wall and restrains wall outward displacements)
RSH3	Pitched and hipped	RMT2	Fibre cement or metal tile			RM99	Masonry, unknown	RTD99	Roof tie-down unknown
RSH4	Pitched with dormers	RMT3	Membrane roofing			RM1	Vaulted masonry	RTDN	Roof tie-down not provided
RSH5	Monopitch	RMT4	Slate			RM2	Shallow-arched masonry	RTDP	Roof tie-down present (a connection that

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
RSH	**Roof shape**	**RMT**	**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
									provides vertical attachment of roof to wall in order to restrain roof from upward displacement, lift-off due to wind)
RSH6	Sawtooth	RMT5	Stone slab			RM3	Composite masonry and concrete roof system		
RSH7	Curved	RMT6	Metal sheets	RE	Earthen				
RSH8	Complex regular	RMT7	Wooden and asphalt shingles			RE99	Earthen, unknown		
RSH9	Complex irregular	RMT8	Vegetative = turf, sod roof (birch bark roof), bamboo, thatched			RE1	Vaulted earthen roof		
RSHO	Roof shape, other	RMT9	Earthen	RC	Concrete				
		RMT10	Solar panelled roofs			RC99	Concrete, unknown		
		RMT11	Tensile membrane			RC1	Cast-in-place beamless reinforced concrete roof		
		RMTO	Roof covering, other			RC2	Cast-in-place beam-supported reinforced concrete roof		
						RC3	Precast concrete roof with reinforced concrete topping		

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
RSH	**Roof shape**	**RMT**	**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
						RC4	Precast concrete roof without reinforced concrete topping		
				RME	Metal				
						RME99	Metal, unknown		
						RME1	Metal beams or trusses supporting light roofing		
						RME2	Metal beams supporting precast concrete slabs		
						RME3	Composite steel deck and concrete slab		
				RWO	Wood				
						RWO99	Wood, unknown		
						RWO1	Wooden beams or trusses and purlins with light roof covering		
						RWO2	Wooden roof structure supporting a heavy flat or domed roof		
						RWO3	Wood-based sheets on rafters or purlins		
						RWO4	Plywood panels or other light-weight panels for roof		

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
RSH	**Roof shape**	**RMT**	**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
						RWO5	Bamboo, straw or thatch roof		
				RFA	Fabric				
						RFA99	Fabric, unknown		
						RFA1	Inflatable or tensile membrane roof		
				RO	Roof material, other				

Comments: 1 - Roof connection

There are two aspects: (a) does the roof have horizontal shear transfer to the walls, and (b) is the roof internally adequately connected? The latter includes Simpson ties preventing wind lift-off. The former is probably sometimes discernible from the street. The latter can be determined only by interior inspection.

Table 12: Floor

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Floor system material		**Floor system type**		**Floor connections**
Attribute_Type_Code	**FLOOR_MAT**		**FLOOR_TYPE**		**FLOOR_CONN**
FN	Floor material non-existent	FNO	No elevated floor (single-storey building)		
F99	Floor material, unknown			FWC99	Floor-wall diaphragm connection unknown
FM	Masonry			FWCN	Floor-wall diaphragm connection not provided
		FM99	Masonry, unknown	FWCP	Floor-wall diaphragm connection present (the role of the connection is to restrain wall out-of-plane forces and to transfer in-plane forces to wall)
		FM1	Vaulted masonry		
		FM2	Shallow-arched masonry		
		FM3	Composite cast-in-place reinforced concrete and masonry floor system		
FE	Earthen				
		FE99	Earthen, unknown		
FC	Concrete				
		FC99	Concrete, unknown		
		FC1	Cast-in-place beamless reinforced concrete floor		
		FC2	Cast-in-place beam-supported reinforced concrete floor		

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Floor system material		**Floor system type**		**Floor connections**
		FC3	Precast concrete floor with reinforced concrete topping		
		FC4	Precast concrete floor without reinforced concrete topping		
FME	Metal				
		FME99	Metal, unknown		
		FME1	Metal beams, trusses, or joists supporting light flooring		
		FME2	Metal beams supporting precast concrete slabs		
		FME3	Composite steel deck and concrete slab		
FW	Wood				
		FW99	Wood, unknown		
		FW1	Wooden beams or trusses and joists supporting light flooring		
		FW2	Wooden beams or trusses and joists supporting heavy flooring		
		FW3	Wood-based sheets on joists or beams		
		FW4	Plywood panels or other light-weight panels for floor		
FO	Floor material, other				

Table 13: Foundation

ID	Level 1 (L1)	Comment
FOS	**Foundation System**	
Attribute_Type_Code	**FOUNDN_SYS**	
FOS99	Unknown foundation system	
FOSSL	Shallow foundation, with lateral capacity	
FOSN	Shallow foundation, no lateral capacity	
FOSDL	Deep foundation, with lateral capacity	
FOSDN	Deep foundation, no lateral capacity	
FOSO	Foundation, other	

Comment: Lateral capacity denotes some form of specific lateral support e.g. tie-beams, foundation walls, inclined piles, piles or piers on wide spread footings, etc.