Taxonomy of Nonstructural Building Components

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To model the seismic performance of nonstructural components, one must define them. A categorization system (or taxonomy) of nonstructural components is developed. Nonstructural components are generally those that are attached to a structure and are not considered part of the structure's vertical- or lateral-force-resisting system. Taxonomic groups are defined to meet ten objectives to ensure that meaningful fragility functions can be created for a group. The study focuses on those components and some contents that contribute significantly to earthquake-induced repair costs, casualties, or loss of use (dollars, deaths, or downtime). Standard or important proposed taxonomic systems are reviewed, in light of how well they meet the ten objectives. Important publications on component seismic fragility are reviewed, including post-earthquake reconnaissance reports. The existing system that comes closest to meeting the design objectives is then selected, modifications are proposed to meet the remaining objectives and to reflect earthquake experience, and the resulting taxonomic system detailed. An important feature of this taxonomic system is that it attempts to distinguish common design or retrofit alternatives that make a difference in seismic performance, such as between braced versus unbraced piping, and between anchored versus unanchored electrical equipment. A taxonomic system that makes these distinctions can be used to assess the benefit of design or retrofit alternatives.

INTRODUCTION

NONSTRUCTURAL COMPONENTS IN PBEE

Several performance-based earthquake engineering (PBEE) loss-estimation procedures have emerged since the 1970s that estimate earthquake repair costs by accumulating the costs to repair individual building components, or to replace the entire facility in case of collapse or excessive repair cost. Many of these methods share four analytical stages (illustrated in Figure 1). In the

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first stage, called the hazard analysis, one or more levels of seismic excitation of interest are selected, and parameterized by an intensity measure such as peak ground acceleration (PGA) or damped elastic spectral acceleration response (S_a); often one or more ground-motion time-histories or response spectra are selected to correspond to the intensity measure. Structural analysis of one kind or another is then used to estimate component forces, deformations, and accelerations. In the third stage, referred to here as the damage analysis, one estimates component damage as a function of the member forces, energy demands, deformations, or accelerations to which the component is subjected during the earthquake. In the last stage, called here the loss analysis, one estimates system performance in terms of total repair cost, casualties, or loss of use ("dollars, deaths, and downtime") based on the physical damage to the system. For example, repair cost is estimated by summing the costs to repair each damaged component, and then adding the contractor's overhead and profit. Examples of loss-estimation methods that use such an approach include Czarnecki (1973), Kustu et al. (1982), and HAZUS (Kircher et al. 1997). Emerging methodologies include that of the Pacific Earthquake Engineering Research (PEER) Center (e.g., Porter 2003) and ATC-58 (e.g., Bachman 2004), for which the present study is performed.

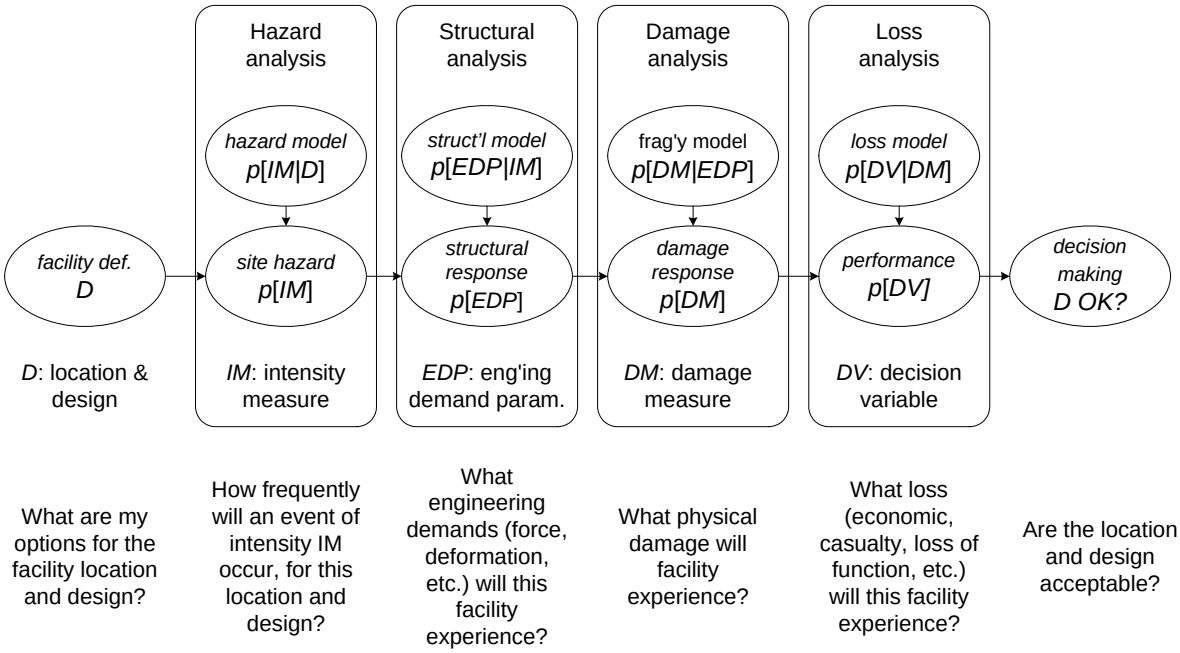

Figure 1. Generic PBEE methodology.

Nonstructural components play an important role in the third and fourth analytical stages (the damage and loss analyses). Damage to architectural finishes, building contents, and building service equipment can dominate repair costs and non-fatal injuries, and can contribute substantially to loss of use. Accurate assessment of performance of nonstructural components can therefore be crucial to a reliable performance-based earthquake engineering evaluation of a facility.

A performance-based earthquake engineering methodology that does carefully treat nonstructural components could be quite valuable in risk-management decision-making, such as choosing between design alternatives for new construction or judging the cost-effectiveness of a seismic retrofit, when decisions affect nonstructural components. To do so, however, requires that the methodology be able to distinguish between the performance of a building with and without the retrofit, or between the performance of the competing design alternatives. The differences can be quite localized, potentially affecting the design or installation of just one out of many structural and nonstructural systems or components. For example, the methodology must distinguish between future earthquake economic and human losses of a particular building with:

- Drywall partitions with screwed connections and metal studs and (a) fixed connection to the soffit above versus (b) sliding or flexible connection to the soffit above;
- Pendant light fixtures (a) with and (b) without seismic restraint;
- Freestanding cabinets (a) with and (b) without seismic restraint.

Each of these choices has an associated cost that is relatively easy to estimate. The challenge is quantifying the benefit, to determine whether the more-expensive alternative is justified. All three distinctions are believed to have a valuable effect on damage and loss. For example, the Federal government has allocated at least $48 million since 1994 to retrofit lights and ceilings in schools (FEMA 2004). Petal's (2004) epidemiological study of casualties in the 1999 Kocaeli (Turkey) earthquake showed that unanchored, freestanding cabinets caused 8,000 of the 80,000 casualties in that event. Performance-based loss-estimation methods should be capable of detecting and measuring the performance difference produced by these risk-mitigation measures.

NEED FOR A NONSTRUCTURAL COMPONENT TAXONOMY

To measure the effects of design changes in nonstructural components, it is necessary first to define nonstructural components. To estimate the seismic performance of nonstructural components and to detect performance differences between common design alternatives requires a rigorous means of categorizing building components in sufficient detail that components with different damageability fall into different categories. For example, ceramic tile is far more fragile than vinyl tile, and caused substantial loss in the Van Nuys Holiday Inn in the 1971 San Fernando earthquake. Other examples that suggest a need for a nonstructural taxonomy include the different performance of full-height versus partial-height gypsum wallboard partitions, unbraced versus braced sprinkler piping, anchored and unanchored electrical equipment, etc. To lump together all varieties of tile finish, of interior partitions, or any of such diverse category of building component must produce large uncertainty in component fragility damageability, and therefore large uncertainty in the system-level performance assessment. Estimates of future earthquake repair costs can be highly sensitive to uncertainty in component damageability (Porter et al. 2002).

To distinguish components with significantly different damageability helps design and retrofit decision-making. If one can estimate the performance of two competing designs, one can calculate the expected economic and life-safety benefits of choosing one over the other. One can address the question, for example, of whether it is cost effective to retrofit suspended ceilings and above-ceiling building-service equipment with seismic bracing, or in new construction, whether future savings justify the extra cost of using sliding connections at the top of interior wallboard partitions.

To make these distinctions and to estimate these performance differences in a design or retrofit situation, one needs a carefully designed categorization system of building components, and a set of fragility functions for each component category that is of interest in that design or retrofit situation.

Such a categorization system is referred to here as a taxonomy, in imitation of the taxonomy of organisms (Linneaus' richly branching system of kingdom, division, phylum, class, order, family, genus, and species). The present study examines taxonomies for nonstructural building components.

Do not confuse the definition of taxonomic groups and their attributes. The terms in which taxonomic groups are defined must be limited to characteristics that are typically shown in construction drawings and specifications, or are visible from inspecting the actual construction. The *attributes* of the class can include damageability, repair cost, repair duration, impact of component failure on operability or life safety, susceptibility to water damage, inflammability, etc. These attributes are important, and can be assigned to each taxonomic group after the group is defined, but they cannot be *part* of its definition, if the taxonomy is to be useful to earthquake engineers.

For example, imagine a suspended ceiling of given dimensions, grid system, tile materials, wall capture conditions, strut and wire-brace restraint conditions, and other conditions such as light fixtures resting on the grid. Some combination of these characteristics define the taxonomic group to which that ceiling belongs. An engineer attempting to estimate the future seismic performance of the ceiling should be able to determine its taxonomic group *without already knowing* its damageability and other attributes, and then look up those attributes in a table or database.

Flexible but not dynamic taxonomy. The taxonomy to be proposed here should not be static, and should allow for the easy addition or modification of groups as future testing or other developments dictate. However, the taxonomy need not be highly dynamic either, restructured with every new query. A slowly developing taxonomic system does not prevent one from dynamically grouping components in different, meaningful ways. For example, in both the Linnaean system and in existing taxonomies of building components, groups are occasionally added, renamed, and removed, without necessitating a complete restructuring of the taxonomic system[1]. One can list species of organism that breath air or that eat meat without restructuring the Linnaean taxonomic system, by performing a query on a database. Similarly, one should be able to list the building components whose engineering demand parameter is peak transient drift by performing a database query that contains attributes for each taxonomic group, without dynamically restructuring the taxonomy.

[1] Revolutions do occur in both domains. There is controversy about how organisms should be classified, whether entirely by branching order or by a combination of branching order and physical and environmental similarity. Similarly, both the UNIFORMAT and MasterFormat systems, described later, are undergoing radical change.

SCOPE, OBJECTIVES AND METHODOLOGY

SCOPE

The present study examines nonstructural components of commercial and engineered residential buildings. The definition of "nonstructural" depends on the results of the study, but in general it refers here to common fixed components that would typically be built as part of the initial construction and do not contribute substantially to structural strength or stiffness. The scope is further limited to components that typically contribute significantly to post-earthquake repair costs, earthquake-induced casualties, and loss of use (dollars, deaths, and downtime). To a limited extent, non-fixed contents are considered, because contents matter to downtime and casualties. Insofar as occupancy matters to the taxonomy, the occupancies within the scope of ATC-58 and therefore this project are listed in Table 1. For reference purposes, the table also lists approximately equivalent occupancy codes within the HAZUS loss-estimation framework (NIBS and FEMA 2003).

Table 1. Occupancies within the present scope

ATC-58 Occupancy	Equivalent HAZUS occupancy classes
Multifamily dwellings	RES3 Multi-Family Dwelling
Temporary lodgings and institutional dormitories	RES4 Temporary Lodging RES5 Institutional Dormitory
Retail trade	COM1 Retail Trade
Warehouse and warehouse retail	COM2 Wholesale Trade
Professional and technical services and government offices	COM4 Professional and Technical Services GOV1 General Services
Hospitals	COM6 Hospital
School classrooms and administration	EDU1 Grade Schools EDU2 Colleges and Universities
University laboratory research	EDU2 Colleges and Universities

OBJECTIVES

A nonstructural component taxonomy for earthquake engineering purposes could be designed to facilitate either the damage analysis (estimation of physical damage as a function of structural response and design), loss analysis (repair cost, casualties, or repair duration, as a function of damage and design), or both. The focus of the present study is on damageability, although some consideration is given to loss. Important features of such a taxonomy include:

1. *Clear definitions*. Two people examining the same nonstructural component should independently assign the same taxonomic group based solely on the text definition of the taxonomic group. One must not need to know about a component's fragility functions in order to assign it to a taxonomic group.

2. *Common fragility functions.* This means three things: (i) All members of the taxonomic group share a common set of damage states relevant to the facility's seismic performance. (ii) All members are sensitive to the same type of excitation (force, deformation, acceleration, etc.). (iii) The excitation at which members enter a particular damage state is identically distributed. The cumulative distribution functions of these capacities are referred to a fragility functions.

3. *Distinguishes differences in seismic performance.* That is, the taxonomy distinguishes supposed earthquake-resistant versions of a component from a non-earthquake resistant version, such as between the "before" and "after" states of common seismic retrofits. For example, if bracing sprinkler piping is believed significantly to reduce damageability, then braced and unbraced piping systems should fall into different taxonomic groups. This is a somewhat more restrictive requirement than "common fragility functions." One can create a fragility function for all varieties of some component without differentiating between varieties that matter to seismic performance. The fragility function for the undifferentiated category will simply have greater uncertainty, and will not enable the analyst to assess the benefit of a change within that category.

4. *Testable*. The taxonomic group is homogenous enough that one can with reasonable confidence perform a set of laboratory tests, analyses, or expert-opinion surveys to establish a single set of fragility functions for the entire group within the constraints of common a research budget (e.g., a single doctoral dissertation).

5. *Amenable to assessment of consequences*. For example, each taxonomic group can be rated in some way (e.g., high, medium, or low) for contribution to historic losses, so as to focus fragility testing efforts. They can be rated in some way (e.g., yes or no) for inflammability, subject to water damage, potential to cause injury, etc., so as to direct subsequent loss assessment.

6. *Flexible.* The taxonomic system should not presuppose future findings of fragility, and it should allow for future addition of taxonomic groups, as new experimental investigations

dictate, and as new materials and systems are developed. For example, it may be found through experimentation that some existing taxonomic group should be subdivided into new groups, because the new groups have less uncertainty on damageability or other attributes. A taxonomy will be judged to be flexible if both (a) it explicitly leaves room for the addition of taxonomic groups, and (b) a mechanism currently exists to do so, such as through an interactive database or a group that maintains and periodically updates the taxonomy. It will be judged to be somewhat flexible if it satisfies only one of these two conditions.

7. *Collectively exhaustive*. The taxonomy should be collectively exhaustive, insofar as any building component can be assigned to a taxonomic group. The taxonomy need not be mutually exclusive. Considering the example cited above for a flexible taxonomy, it will be desirable to have available both older or larger groups and newer or finer groups for purposes of comparing or refining analyses.

8. *Simple*. The taxonomy has as few groups as possible, while still meeting the other requirements. It is problematic to define what is simple, but for present purposes, a taxonomy will be judged simple if it contains fewer than 100 groups, somewhat simple if it both contains between 100 and 1,000 groups and those groups are arranged hierarchically so that one could find a desired group without being familiar with the entire taxonomy.

9. *Collapsible.* It is desirable to be able to define common combinations and relative quantities of nonstructural components so that fragility or vulnerability functions could be created by aggregating the fragilities or vulnerabilities of detailed components, while still distinguishing design or retrofit alternatives. For example, it would be desirable to create one vulnerability function for drift-sensitive nonstructural components of current-code-compliant class-A office buildings that meet a set of observable seismic resistance criteria. A taxonomy will be judged to be collapsible if taxonomic groups can be combined and the resulting combinations still distinguish differences in seismic performance.

10. *Familiar to construction contractors and engineering practitioners*. It is desirable, though not necessary, that engineers and construction contractors be familiar with the taxonomic system, to facilitate communication and, particularly, for repair-cost estimation. If the new taxonomic system corresponds readily to an existing taxonomic system, it can give engineers access to cost data, historical databases, and tools for construction scheduling. Employing or

elaborating an existing taxonomic system will also help simplify the maintenance and further development of the taxonomic system.

METHODOLOGY

The taxonomy is developed first by reviewing the desired features, in consultation with an oversight committee of scholars and practitioners familiar with the objectives and principles of performance-based earthquake engineering. Next, existing taxonomic systems are reviewed, to see how well each satisfies the objectives listed above. Relevant damage data are reviewed, including publications on fragility testing and observed empirical seismic performance, to identify design alternatives that make a material difference to seismic performance and might therefore impact the design of the taxonomy.

It is anticipated that no existing, accepted taxonomy satisfies all the objectives. The existing taxonomy that in some way comes closest to satisfying the objectives is then identified, and modifications are proposed to meet the remaining objectives. A sample of the resulting taxonomic system is then created. The proposed system and the sample are then presented to the oversight committee for review. That is the stage of the present draft of this study. In the final draft, after review and commentary by the oversight committee, a final taxonomic system will be proposed.

LITERATURE REVIEW

With the objectives and methodology stated, a review of relevant literature is now presented. Four general categories of prior work are examined:

- Taxonomies designed for use in earthquake engineering
- General building component taxonomies
- Laboratory testing and surveys to quantify component damageability, and
- Post-earthquake reconnaissance reports.

The last two groups are included in the review because of their relevance to selecting or designing a taxonomy that reflects material differences in the seismic performance of.

EXISTING TAXONOMIES DESIGNED FOR EARTHQUAKE ENGINEERING

International Code Council (2000); ASCE 7-05 (ASCE 2005). The International Building Code and ASCE's Minimum Design Loads for Buildings and Other Structures both contain (in a way) a taxonomy of nonstructural components. Table 2 contains parameters of these two documents' seismic design requirements for architectural components. Table 3 shows a similar taxonomy for mechanical and electrical components. Because it comes from a building code, the taxonomy is familiar to engineers, although perhaps not to construction contractors because of its location in a chapter dedicated to structural design. It is short and simple. However, its disadvantages for present purposes are numerous. The definitions are qualitative, somewhat vaguely defined, and do not appear to be collectively exhaustive. For example, what is the meaning of limited-deformability veneer, how is it distinguished from low-deformability veneer, and is there no such thing as moderate or high-deformability veneer? These categories would be circularly defined if used in a taxonomy for damage analysis. The groups are too large to share common functions, to be testable, to be amenable to the assessment of consequences, or to distinguish seismic performance of similar components installed differently, as with braced versus unbraced sprinkler pipe.

Table 2. Architectural component categories in the IBC and ASCE 7 (ICC 2000 and ASCE 2005)

Architectural Component or Element	a_p [a]	R_p [b]
Interior Nonstructural Walls and Partitions [b]		
Plain (unreinforced) masonry walls	1.0	1.5
All other walls and partitions	1.0	2.5
Cantilever Elements (Unbraced or braced to structural frame below its center of mass)		
Parapets and cantilever interior nonstructural walls	2.5	2.5
Chimneys and stacks where laterally braced or supported by the structural frame	2.5	2.5
Cantilever Elements (Braced to structural frame above its center of mass)		
Parapets	1.0	2.5
Chimneys and Stacks	1.0	2.5
Exterior Nonstructural Walls [b]	1.0[b]	2.5
Exterior Nonstructural Wall Elements and Connections [b]		
Wall Element	1.0	2.5
Body of wall panel connections	1.0	2.5
Fasteners of the connecting system	1.25	1.0
Veneer		
Limited deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.5
Penthouses (except where framed by an extension of the building frame)	2.5	3.5
Ceilings		
All	1.0	2.5
Cabinets		
Storage cabinets and laboratory equipment	1.0	2.5
Access Floors		
Special access floors (designed in accordance with Section13.5.7.2)	1.0	2.5
All other	1.0	1.5
Appendages and Ornamentations	2.5	2.5
Signs and Billboards	2.5	2.5
Other Rigid Components		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability materials and attachments	1.0	1.5
Other Flexible Components		
High deformability elements and attachments	2.5	3.5
Limited deformability elements and attachments	2.5	2.5
Low deformability materials and attachments	2.5	1.5

[a] A lower value for a_p shall not be used unless justified by detailed dynamic analysis. The value for a_p shall not be less than 1.00. The value of $a_p = 1$ is for rigid components and rigidly attached components. The value of $a_p = 2.5$ is for flexible components and flexibly attached components. See Section 11.2 for definitions of rigid and flexible.

[b] Where flexible diaphragms provide lateral support for concrete or masonry walls and partitions, the design forces for anchorage to the diaphragm shall be as specified in Section 12.11.2.

Table 3. Mechanical and electrical component categories in the IBC and ASCE 7 (ICC 2000 and ASCE 2005)

Mechanical and Electrical Components	a_p[a]	R_p
Air-side HVAC, fans, air handlers, air conditioning units, cabinet heaters, air distribution boxes, and other mechanical components constructed of sheet metal framing.	2.5	3.0
Wet-side HVAC, boilers, furnaces, atmospheric tanks and bins, chillers, water heaters, heat exchangers, evaporators, air separators, manufacturing or process equipment, and other mechanical components constructed of high deformability materials.	1.0	2.5
Engines, turbines, pumps, compressors, and pressure vessels not supported on skirts and not within the scope of Section 15.	1.0	2.5
Skirt-supported pressure vessels not within the scope of Section15.	2.5	2.5
Elevator and escalator components.	1.0	2.5
Generators, batteries, inverters, motors, transformers, and other electrical components constructed of high deformability materials.	1.0	2.5
Motor control centers, panel boards, switch gear, instrumentation cabinets, and other components constructed of sheet metal framing.	2.5	3.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof mounted chimneys, stacks, cooling and electrical towers laterally braced below their center of mass.	2.5	3.0
Roof mounted chimneys, stacks, cooling and electrical towers laterally braced above their center of mass.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical or electrical components.	1.0	1.5
Vibration Isolated Components and Systems [b]		
Components and systems isolated using neoprene elements and neoprene isolated floors with built-in or separate elastomeric snubbing devices or resilient perimeter stops.	2.5	2.5
Spring isolated components and systems and vibration isolated floors closely restrained using built-in or separate elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components and systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices and suspended internally isolated components.	2.5	2.5
Distribution Systems		
Piping in accordance with ASME B31, including in-line components with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31, including in-line components, constructed of high or limited deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high or limited deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping and tubing constructed of low deformability materials, such as cast iron, glass, and nonductile plastics.	2.5	3.0
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials with joints made by means other than welding or brazing.	2.5	6.0
Ductwork, including in-line components, constructed of low deformability materials, such as cast iron, glass, and nonductile plastics.	2.5	3.0
Electrical conduit, bus ducts, rigidly mounted cable trays, and plumbing.	1.0	2.5
Manufacturing or process conveyors (nonpersonnel).	2.5	3.0
Suspended cable trays.	2.5	6.0

[a] A lower value for a_p is permitted where justified by detailed dynamic analyses. The value for a_p shall not be less than 1.0. The value of a_p equal to 1.0 is for rigid components and rigidly attached components. The value of a_p equal to 2.5 is for flexible components and flexibly attached components.

[b] Components mounted on vibration isolators shall have a bumper restraint or snubber in each horizontal direction. The design force shall be taken as $2F_p$ if the nominal clearance (air gap) between the equipment support frame and restraint is greater than 1/4 in. If the nominal clearance specified on the construction documents is not greater than 1/4 in., the design force is permitted to be taken as F_p.

HAZUS (NIBS and FEMA 2003). HAZUS is a FEMA-sponsored standard, nationally applicable software methodology for assessing earthquake risk. Subsequent versions of the software added the ability to assess risk from hurricanes and floods. In the process of developing its loss-estimation algorithm, HAZUS' developers created a taxonomy of common nonstructural components and contents of buildings, shown below in Table 4. It is simple and amenable to the assessment of consequences (that being its purpose). It has important deficiencies for present purposes. The groups border on being too large to be testable. It is not intended to reflect differences in seismic performance between common design or retrofit alternatives. For example, it does not distinguish between restrained and unrestrained freestanding cabinets (relevant, as noted earlier, to injury epidemiology) or between anchored and unanchored electrical equipment (relevant to repair costs, repair duration, and post-earthquake operability). Some important components are missing: note the absence of suspended ceilings and glazing from the taxonomy.

Table 4. HAZUS 99 taxonomy of building nonstructural components and contents

Type	Item	Drift-Sensitive*	Acceleration-Sensitive*
Architectural	Nonbearing Walls/Partitions	●	○
	Cantilever Elements and Parapets		●
	Exterior Wall Panels	●	○
	Veneer and Finishes	●	○
	Penthouses	●	
	Racks and Cabinets		●
	Access Floors		●
	Appendages and Ornaments		●
Mechanical and Electrical	General Mechanical (boilers, etc.)		●
	Manufacturing and Process Machinery		●
	Piping Systems	○	●
	Storage Tanks and Spheres		●
	HVAC Systems (chillers, ductwork, etc.)	○	●
	Elevators	○	●
	Trussed Towers		●
	General Electrical (switchgear, ducts, etc.)	○	●
	Lighting Fixtures		●
Contents	File Cabinets, Bookcases, etc.		●
	Office Equipment and Furnishings		●
	Computer/Communication Equipment		●
	Nonpermanent Manufacturing Equipment		●
	Manufacturing/Storage Inventory		●
	Art and other Valuable Objects		●

* Solid dots indicate primary cause of damage, open dots indicate secondary cause of damage

Porter (2000). The current author presented a component taxonomy designed for performance-based earthquake engineering. It is based on the RS Means Assembly numbering system (described later), extended with a "condition" attribute added to each RS Means category,

to account for differences in installation or other characteristics that matter to seismic performance. For example, the taxonomy distinguishes between braced and unbraced sprinkler piping, anchored and unanchored generators, etc. It includes a judgment of the relevant engineering demand parameter (the seismic excitation most likely to cause damage). It lists categories of common, potentially damageable components in nine UNIFORMAT divisions. Since it is based on UNIFORMAT and RS Means, the taxonomy offers clear, familiar definitions and ready application of published databases of cost and repair duration, useful in assessing consequences. (For a small, illustrative subset of the taxonomy, fragility functions, repair costs, and repair durations are tabulated; these have been supplemented in Porter et al. 2002 and Beck et al. 2002. Eighty-three fragility functions and repair-cost distributions for common components are currently available.) The categories are small enough to be tested. The provision of the condition attribute allows for taxonomic groups to be small enough to have common fragility functions and to distinguish seismic performance. Its categories are not collectively exhaustive; no components in Divisions 10 (special construction) and higher are included. Furthermore, many higher-level aggregations of categories are not broken out into fine detail. For example, exterior glazing is not differentiated by pane size or gap size, nor are interior wallboard partitions differentiated between full-height, partial-height, etc. Since it is an extension of the RS Means assembly-numbering system, a complete listing would be very large, and its use for present purposes would potentially raise concerns about copyrights and costs of manuals.

Taghavi and Miranda (2003). These authors describe a Microsoft Access database of the seismic performance of nonstructural components of commercial buildings. The database includes a taxonomy of components, as well as example photographs and attributes of fragility, repair cost, repair actions, and damage consequences in terms of building functionality and life-safety threat. The taxonomic groups are identical to those of RS Means assemblies (Miranda, 2005). As it relies on the RS Means categories, the taxonomy uses familiar, clear terms, with categories small enough to be tested within a single doctoral dissertation. However, for the same reason, the complete listing would be very large, and its use for present purposes would potentially raise concerns about copyrights and costs of manuals. As with RS Means assembly-numbering system, the taxonomy does not distinguish seismic performance features. For example, no distinction is made between braced and unbraced suspended ceilings, between braced and unbraced automatic sprinklers, and between mechanical and electrical equipment with and without seismic restraint.

Antaki (2004) offers a conceptual taxonomy of all fixed facilities by expanding on a scheme developed by the Electric Power Research Institute as part of the Seismic Qualification of Utilities Guidelines (SQUG). The SQUG guidelines are used to determine whether electrical and mechanical equipment in energy facilities are adequately seismically resistant. They use checklists first to identify equipment within a category and then to assess the features of the equipment to determine seismic adequacy. SQUG's Generic Implementation Procedure (GIP) documents this methodology. It comprises a book and 50 or so manuals, and has been republished as US Department of Energy guide DOE-EH-0545. Antaki proposes an expansion of this procedure to address all fixed facilities. His taxonomy has four levels: (i) categories are defined in terms of the discipline of the engineers who design the system; (ii) classes and (iii) groups defined per the SQUG inclusion system; and (iv) attributes that are believed largely to be determine whether the component is seismically resistant: material; design compliant with national standards for normal operation; quality of fabrication; effects of operation on seismic resistance; and effects of maintenance on seismic resistance. Figure 2 partially illustrates this taxonomic system. Its tree-like structure allows the taxonomy to be collapsed. The framework omits architectural elements, so cannot be said to be collectively exhaustive. To the extent that it is developed, some of the components are vaguely defined, e.g., under static mechanical components, what is "equipment" if it is distinct from "boilers?" Groups appear to be too large to be testable or readily amenable to the assessment of consequences. For example, "frames" in the structural-element class: how would one test these or assess their repair cost or repair duration as a single, monolithic group? Because the taxonomy has been developed to some extent by and for a specialty within electrical and mechanical engineering, some of the definitions would be unfamiliar to earthquake engineers.

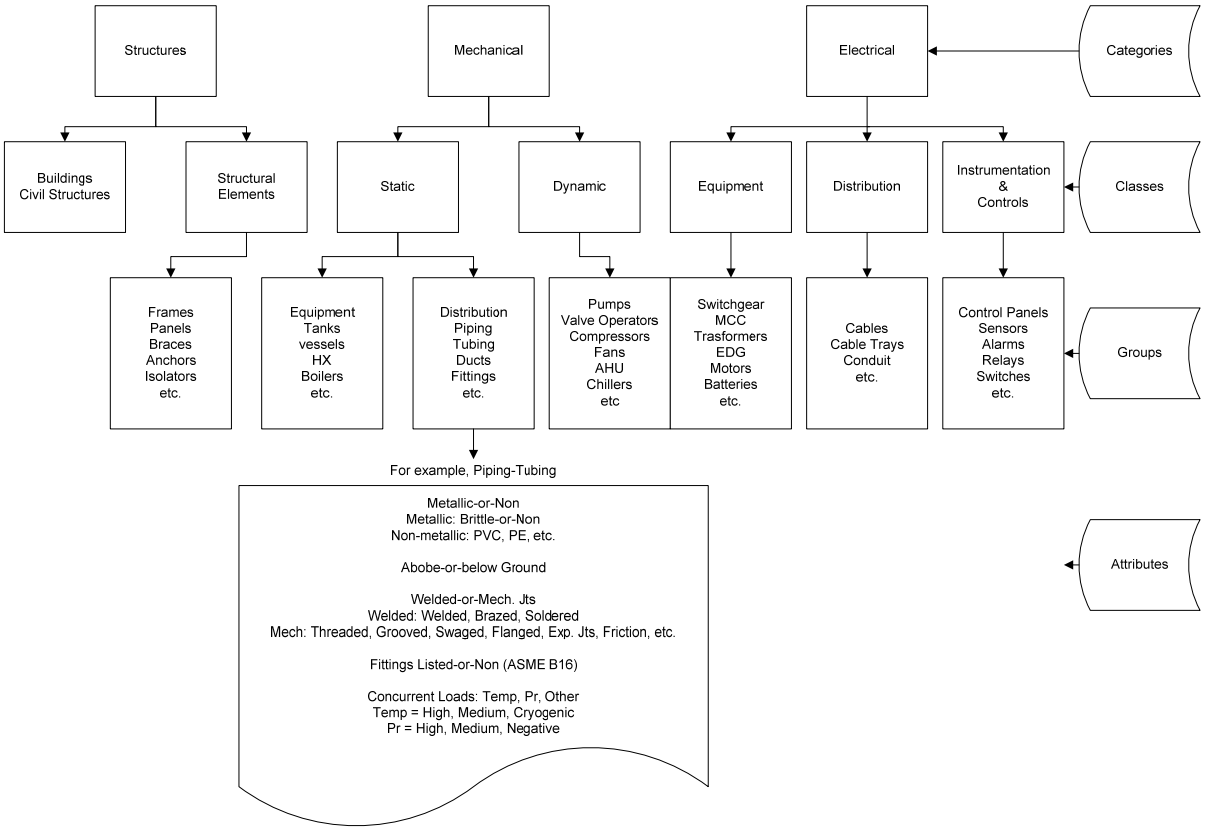

Figure 2. A conceptual taxonomy of all fixed facilities (Antaki 2004)

GENERAL BUILDING-COMPONENT TAXONOMIES

UNIFORMAT-II. The Construction Specification Institute (CSI) has produced a taxonomic system for building systems, the current version of which is called UNIFORMAT-II (ASTM 2002). Figure 3 summarizes its framework for categorizing the built environment; only the shaded blocks (construction, buildings, and sitework) are relevant here. Table 5 summarizes the UNIFORMAT-II classification of building elements. UNIFORMAT-II includes three levels of increasing detail, in a branching structure: Level 1—Major Group Elements, Level 2—Group Elements, and Level 3—Individual Elements. Every Level-1 taxonomic group includes one or more Level-2 taxonomic groups that belong only to that Level-1 taxonomic group. Similarly, every Level-2 taxonomic group includes one or more Level-3 groups that belong only to that Level-2 group. For example, within the Level-1 group Shells is a Level-2 group called Exterior Closure. Within Exterior Closure is a Level-3 group called Exterior Windows.

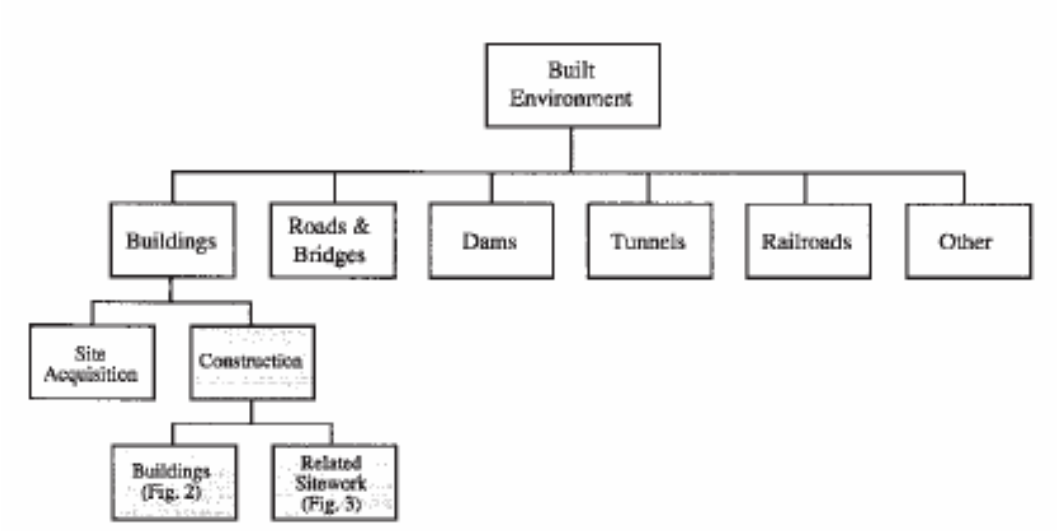

Figure 3. UNIFORMAT-II framework of the built environment. Only construction and buildings are relevant here.

Table 5. UNIFORMAT-II classification of building elements.

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations
		A1020 Special Foundations
		A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation
		A2020 Basement Walls
B SHELL	B10 Super Structure	B1010 Floor Construction
		B1020 Roof Construction
	B20 Exterior Enclosure	B2010 Exterior Walls
		B2020 Exterior Windows
		B2030 Exterior Doors
	B30 Roofing	B3010 Roof Coverings
		B3020 Roof Openings
C INTERIORS	C10 Interior Construction	C1010 Partitions
		C1020 Interior Doors
		C1030 Fittings
	C20 Stairs	C2010 Stair Construction
		C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes
		C3020 Floor Finishes
		C3030 Ceiling Finishes
D SERVICES	D10 Conveying	D1010 Elevators & Lifts
		D1020 Escalators & Moving Walks
		D1090 Other Conveying Systems
	D20 Plumbing	D2010 Plumbing Fixtures
		D2020 Domestic Water Distribution
		D2030 Sanitary Waste
		D2040 Rain Water Drainage
		D2090 Other Plumbing Systems
	D30 HVAC	D3010 Energy Supply
		D3020 Heat Generating Systems
		D3030 Cooling Generating Systems
		D3040 Distribution Systems
		D3050 Terminal & Package Units
		D3060 Controls & Instrumentation
		D3070 Systems Testing & Balancing
		D3090 Other HVAC Systems & Equipment
	D40 Fire Protection	D4010 Sprinklers
		D4020 Standpipes
		D4030 Fire Protection Specialties
		D4090 Other Fire Protection Systems
	D50 Electrical	D5010 Electrical Service & Distribution
		D5020 Lighting and Branch Wiring
		D5030 Communications & Security
		D5090 Other Electrical Systems
E EQUIPMENT & FURNISHINGS	E10 Equipment	E1010 Commercial Equipment
		E1020 Institutional Equipment
		E1030 Vehicular Equipment
		E1090 Other Equipment
	E20 Furnishings	E2010 Fixed Furnishings
		E2020 Movable Furnishings
F SPECIAL CONSTRUCTION & DEMOLITION	F10 Special Construction	F1010 Special Structures
		F1020 Integrated Construction
		F1030 Special Construction Systems
		F1040 Special Facilities
		F1050 Special Controls and Instrumentation
	F20 Selective Building Demolition	F2010 Building Elements Demolition
		F2020 Hazardous Component Abatement

The advantages of UNIFORMAT-II for present purposes are that it is already well defined, the construction industry is familiar with and accepts it, and the American Society of Testing and Materials will continue to maintain it for some time. Its groups are collectively exhaustive and small in number: only 55 groups, and a listing occupies only one page. Its disadvantages are numerous, however. The groups are not quite clearly defined: it is unclear, for example, whether the interior finish to exterior walls belongs to B2010 (Exterior Walls) or C3010 (Wall Finishes). The groups are too large reasonably to share common fragility functions or to be testable. They do not distinguish differences in seismic performance. For example, D4010, Sprinklers, has no subcategories to distinguish braced sprinkler pipes from unbraced. There is no distinction between exterior walls of precast concrete, stucco, timber, or gypsum wallboard. The overly large grouping prevents the taxonomic system from facilitating cost estimation or repair scheduling, as the groups are too large to associate historical databases or manuals of repair costs.

NISTIR 6389. NIST (1999) proposed a revision to UNIFORMAT-II to include a fourth level of definition to augment the three levels in the 1997 standard. Like UNIFORMAT-II, NISTIR 6389 is oriented around building systems, which may involve diverse trades and materials. Its additional level of detail, for example, distinguishes fixed partitions (C1011 in the proposed numbering system) from site-built compartment cubicles (C1015) and windows (B2021) from curtain walls (B2022). Because it is an extension of UNIFORMAT-II, it is collectively exhaustive and would be familiar to construction contractors and engineering practitioners. The revision makes the taxonomy more clearly defined, e.g., eliminating the ambiguity about the group to which interior finishes on exterior walls belongs[2]. The groups are smaller and more testable than in UNIFORMAT-II, and more amenable to assessing consequences. A complete listing takes only three pages (see Table 6), and contains 274 categories. Nonetheless, the authors particularly note the point that with the greater level of detail comes readier access to existing cost data, stronger validation of new cost estimates against the costs of similar past construction, and easier construction scheduling. However, there are limitations to the revision for present purposes: even with the additional level of detail, the revision does not distinguish differences in seismic performance. For example, there is no distinction between braced and unbraced sprinkler piping or between precast concrete, stucco, wood, and gypsum wallboard exterior walls.

[2] Some additions or clarifications would be desirable to make the taxonomy useful for PBEE, especially the addition of separate categories for structural elements of the gravity and lateral-force-resisting systems.

Table 6. NISTIR 6389 proposed level 4 for the UNIFORMAT-II Classification of Buildings

Level 3 Elements	Level 4 Sub-Elements
A1010 Standard Foundations	A1011 Wall Foundations A1012 Column Foundations & Pile Caps A1013 Perimeter Drainage & Insulation
A1020 Special Foundations	A1021 Pile Foundations A1022 Grade Beams A1023 Caissons A1024 Underprinting A1025 Dewatering A1026 Raft Foundations A1027 Pressure Injected Grouting A1029 Other Special Conditions
A1030 Slab on Grade	A1031 Standard Slab on Grade A1032 Structural Slab on Grade A1033 Inclined Slab on Grade A1034 Trenches, Pits & Bases A1035 Under-Slab Drainage & Insulation
A2010 Basement Excavation	A2011 Excavation for Basements A2012 Structure Back Fill & Compaction A2013 Shoring
A2020 Basement Walls	A2021 Basement Wall Construction A2022 Moisture Protection A2023 Basement Wall Insulation A2024 Interior Skin
B1010 Floor Construction	B1011 Suspended Basement Floors Construction B1012 Upper Floors Construction B1013 Balcony Floors Construction B1014 Ramps B1015 Exterior Stairs and Fire Escapes B1016 Floor Raceway Systems B1019 Other Floor Construction
B1020 Roof Construction	B1021 Flat Roof Construction B1022 Pitched Roof Construction B1023 Canopies B1029 Other Roof Systems
B2010 Exterior Walls	B2011 Exterior Wall Construction B2012 Parapets B2013 Exterior Louvers, Screens, and Fencing B2014 Exterior Sun Control Devices B2015 Balcony Walls & Handrails B2016 Exterior Soffits
B2020 Exterior Windows	B2021 Windows B2022 Curtain Walls B2023 Storefronts
B2030 Exterior Doors	B2031 Glazed Doors & Entrances B2032 Solid Exterior Doors B2033 Revolving Doors B2034 Overhead Doors B2039 Other Doors & Entrances
B3010 Roof Coverings	B3011 Roof Finishes B3012 Traffic Toppings & Paving Membranes B3013 Roof Insulation & Fill B3014 Flashings & Trim B3015 Roof Eaves and Soffits B3016 Gutters and Downspouts
B3020 Roof Openings	B3021 Glazed Roof Openings B3022 Roof Hatches B3023 Gravity Roof Ventilators
C1010 Partitions	C1011 Fixed Partitions C1012 Demountable Partitions C1013 Retractable Partitions C1014 Site Built Toilet Partitions C1015 Site Built Compartments Cubicles C1016 Interior Balustrades and Screens C1017 Interior Windows & Storefronts
C1020 Interior Doors	C1021 Interior Doors C1022 Interior Door Frames C1023 Interior Door Hardware C1024 Interior Door Wall Opening Elements C1025 Interior Door Sidelights & Transoms C1026 Interior Hatches & Access Doors C1027 Door Painting & Decoration
C1030 Fittings	C1031 Fabricated Toilet Partitions C1032 Fabricated Compartments & Cubicles C1033 Storage Shelving and Lockers C1034 Ornamental Metals and Handrails C1035 Identifying Devices C1036 Closet Specialties C1037 General Fittings & Misc. Metals
C2010 Stair Construction	C2011 Regular Stairs C2012 Curved Stairs C2013 Spiral Stairs C2014 Stair Handrails and Balustrades
C2020 Stair Finishes	C2021 Stair, Tread, and Landing Finishes C2022 Stair Soffit Finishes C2023 Stair Handrail & Balustrade Finishes

Table 6. NISTIR 6389 proposed level 4 for the UNIFORMAT-II Classification of Buildings (cont.)

C3010 Wall Finishes	C3011 Wall Finishes to Inside Exterior Walls C3012 Wall Finishes to Interior Walls C3013 Column Finishes
C3020 Floor Finishes	C3021 Floor Toppings C3022 Traffic Membranes C3023 Hardeners and Sealers C3024 Flooring C3025 Carpeting C3026 Bases, Curbs and Trim C3027 Access Pedastal Flooring
C3030 Ceiling Finishes	C3031 Ceiling Finishes C3032 Suspended Ceilings C3033 Other Ceilings
D1010 Elevators & Lifts	D1011 Passenger Elevators D1012 Freight Elevators D1013 Lifts
D1020 Escalators & Moving Walks	D1021 Escalators D1022 Moving Walks
D1090 Other Conveying Systems	D1091 Dumbwaiters D1092 Pneumatic Tube Systems D1093 Hoists & Cranes D1094 Conveyors D1095 Chutes D1096 Turntables D1097 Baggage Handling & Loading Systems D1098 Transportation Systems
D2010 Plumbing Fixtures	D2011 Water Closets D2012 Urinals D2013 Lavatories D2014 Sinks D2015 Bathtubs D2016 Wash Fountains D2017 Showers D2018 Drinking Fountains and Coolers D2019 Bidets and Other Plumbing Fixtures
D2020 Domestic Water Distribution	D2021 Cold Water Service D2022 Hot Water Service D2023 Domestic Water Supply Equipment
D2030 Sanitary Waste	D2031 Waste Piping D2032 Vent Piping D2033 Floor Drains D2034 Sanitary Waste Equipment D2035 Pipe Insulation
D2040 Rain Water Drainage	D2041 Pipe & Fittings D2042 Roof Drains D2043 Rainwater Drainage Equipment D2044 Pipe Insulation
D2090 Other Plumbing Systems	D2091 Gas Distribution D2092 Acid Waste Systems D2093 Interceptors D2094 Pool Piping and Equipment D2095 Decorative Fountain Piping Devices D2099 Other Piping Systems
D3010 Energy Supply	D3011 Oil Supply System D3012 Gas Supply System D3013 Coal Supply System D3014 Steam Supply System D3015 Hot Water Supply System D3016 Solar Energy System D3017 Wind Energy System
D3020 Heat Generating Systems	D3021 Boilers D3022 Boiler Room Piping & Specialties D3023 Auxiliary Equipment D3024 Insulation
D3030 Cooling Generating Systems	D3031 Chilled Water Systems D3032 Direct Expansion Systems
D3040 Distribution Systems	D3041 Air Distribution Systems D3042 Exhaust Ventilation Systems D3043 Steam Distribution Systems D3044 Hot Water Distribution D3045 Chilled Water Distribution D3046 Change-over Distribution System D3047 Glycol Distribution Systems
D3050 Terminal & Package Units	D3051 Terminal Self-Contained Units D3052 Package Units
D3060 Controls & Instrumentation	D3061 Heating Generating Systems D3062 Cooling Generating Systems D3063 Heating/Cooling Air Handling Units D3064 Exhaust & Ventilating Systems D3065 Hoods and Exhaust Systems D3066 Terminal Devices D3067 Energy Monitoring & Control D3068 Building Automation Systems D3069 Other Controls & Instrumentation
D3070 Systems Testing & Balancing	D3071 Piping System Testing & Balancing D3072 Air Systems Testing & Balancing D3073 HVAC Commissioning D3079 Other Systems Testing and Balancing
D3090 Other HVAC Systems & Equipment	D3091 Special Cooling Systems & Devices D3092 Special Humidity Control D3093 Dust & Fume Collectors D3094 Air Curtains D3095 Air Purifiers D3096 Paint Spray Booth Ventilation D3097 General Construction Items (HVAC)
D4010 Sprinklers	D4011 Sprinkler Water Supply D4012 Sprinkler Pumping Equipment D4013 Dry Sprinkler System

Table 6. NISTIR 6389 proposed level 4 for the UNIFORMAT-II Classification of Buildings (cont.)

D4020 Standpipes	D4021 Standpipe Water Supply D4022 Pumping Equipment D4023 Standpipe Equipment D4024 Fire Hose Equipment
D4030 Fire Protection Specialties	D4031 Fire Extinguishers D4032 Fire Extinguisher Cabinets
D4090 Other Fire Protection Systems	D4091 Carbon Dioxide Systems D4092 Foam Generating Equipment D4093 Clean Agent Systems D4094 Dry Chemical System D4095 Hood & Duct Fire Protection
D5010 Electrical Service & Distribution	D5011 High Tension Service & Dist. D5012 Low Tension Service & Dist.
D5020 Lighting & Branch Wiring	D5021 Branch Wiring Devices D5022 Lighting Equipment
D5030 Communications & Security	D5031 Public Address & Music Systems D5032 Intercommunication & Paging Syst. D5033 Telephone Systems D5034 Call Systems D5035 Television Systems D5036 Clock and Program Systems D5037 Fire Alarm Systems D5038 Security and Detection Systems D5039 Local Area Networks
D5090 Other Electrical System	D5091 Grounding Systems D5092 Emergency Light & Power Systems D5093 Floor Raceway Systems D5094 Other Special Systems & Devices D5095 General Construction Items (Elect.)
E1010 Commercial Equipment	E1011 Security & Vault Equipment E1012 Teller and Service Equipment E1013 Registration Equipment E1014 Checkroom Equipment E1015 Mercantile Equipment E1016 Laundry & Dry Cleaning Equipment E1017 Vending Equipment E1018 Office Equipment
E1020 Institutional Equipment	E1021 Ecclesiastical Equipment E1022 Library Equipment E1023 Theater & Stage Equipment E1024 Instrumental Equipment E1025 Audio-visual Equipment E1026 Detention Equipment E1027 Laboratory Equipment E1028 Medical Equipment E1029 Other Institutional Equipment
E1030 Vehicular Equipment	E1031 Vehicular Service Equipment E1032 Parking Control Equipment E1033 Loading Dock Equipment E1039 Other Vehicular Equipment
(Note E1090 moved right for convenience) →	

E2010 Fixed Furnishings	E2011 Fixed Artwork E2012 Fixed Casework E2013 Blinds and Other Window Treatment E2014 Fixed Floor Grilles and Mats E2015 Fixed Multiple Seating E2016 Fixed Interior Landscaping
E2020 Movable Furnishings	E2021 Movable Artwork E2022 Furniture & Accessories E2023 Movable Rugs and Mats E2024 Movable Interior Landscaping
F1010 Special Structures	F1011 Air Supported Structures F1012 Pre-engineered Structures F1013 Other Special Structures
F1020 Integrated Construction	F1021 Integrated Assemblies F1022 Special Purpose Rooms F1023 Other Integrated Construction
F1030 Special Construction Systems	F1031 Sound, Vibration & Seismic Const. F1032 Radiation Protection F1033 Special Security Systems F1034 Vaults F1039 Other Special Construction Systems
F1040 Special Facilities	F1041 Aquatic Facilities F1042 Ice Rinks F1043 Site Constructed Incinerators F1044 Kennels & Animal Shelters F1045 Liquid & Gas Storage Tanks F1049 Other Special Facilities
F1050 Special Controls & Instrumentation	F1051 Recording Instrumentation F1052 Building Automation System F1059 Other Special Controls & Instrumentation
F2010 Building Elements Demolition	F2011 Building Interior Demolition F2012 Building Exterior Demolition
F2020 Hazardous Components Abatement	F2021 Removal of Hazardous Components F2022 Encapsulation of Hazardous Components
E1090 Other Equipment	E1091 Maintenance Equipment E1092 Solid Waste Handling Equipment E1093 Food Service Equipment E1094 Residential Equipment E1095 Unit Kitchens E1097 Window Washing Equipment E1099 Other Equipment

Construction Specifications Institute (2004). Along with UNIFORMAT-II, the MasterFormat classification system represents the second of the two major systems used by the United States construction industry for classifying building construction work. MasterFormat subdivides building components by materials and trades, as opposed to the systems orientation of UNIFORMAT-II and NISTIR 6389. In MasterFormat, for example, concrete, masonry, and metals are three distinct divisions. It is an organizational standard for construction specifications for materials, products, and systems in most commercial and institutional building projects in the U.S. and Canada. It has been recently expanded (MasterFormat Expansion Task Team 2003) to address rapidly expanding building technologies such as integrated automation systems and electronic safety and security systems. It has 50 basic divisions (increased from 16 of prior versions) that constitute the highest-level grouping, and two to three layers of subcategories identified by two-digit pairs, so that the lowest-level grouping has either a six- or eight-digit numerical identifier. A list of the highest-level groupings is shown in Table 7.

Because it is used for construction specifications, the MasterFormat taxonomy is clearly defined. The system is highly detailed: a complete listing of its classification scheme takes 170 pages without explanatory text. It is familiar to construction contractors and others. The high level of detail presents problems. For example, it distinguishes the metal studs of interior partitions from the wallboard-partition sheathing, showing these two components in separate taxonomic groups. Certain groups do seem to represent larger assemblies, however. For example, while there are separate groups for metal framing and for gypsum wallboard sheathing of wallboard partitions, there is also a group for gypsum board assemblies. Because of these redundant assembly-level groups, the system is testable and amenable to the assessment of consequences, but is not collectively exhaustive. As with other taxonomic system that were not designed with PBEE in mind, it does not distinguish differences in seismic performance.

Table 7. MasterFormat divisions

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP	*Division 24 Reserved*
Division 00 Procurement and Contracting Requirements	Division 25 Integrated Automation
SPECIFICATIONS GROUP	Division 26 Electrical
GENERAL REQUIREMENTS SUBGROUP	Division 27 Communications
Division 01 General Requirements	Division 28 Electronic Safety and Security
FACILITY CONSTRUCTION SUBGROUP	*Division 29 Reserved*
Division 02 Existing Conditions	SITE AND INFRASTRUCTURE SUBGROUP
Division 03 Concrete	*Division 30 Reserved*
Division 04 Masonry	Division 31 Earthwork
Division 05 Metals	Division 32 Exterior Improvements
Division 06 Wood, Plastics, and Composites	Division 33 Utilities
Division 07 Thermal and Moisture Protection	Division 34 Transportation
Division 08 Openings	Division 35 Waterway and Marine Construction
Division 09 Finishes	*Division 36 Reserved*
Division 10 Specialties	*Division 37 Reserved*
Division 11 Equipment	*Division 38 Reserved*
Division 12 Furnishings	*Division 39 Reserved*
Division 13 Special Construction	PROCESS EQUIPMENT SUBGROUP
Division 14 Conveying Equipment	Division 40 Process Integration
Division 15 Reserved	Division 41 Material Processing and Handling Equipment
Division 16 Reserved	Division 42 Process Heating, Cooling, and Drying Equipment
Division 17 Reserved	Division 43 Process Gas and Liquid Handling, Purification, and Storage Equipment
Division 18 Reserved	Division 44 Pollution Control Equipment
Division 19 Reserved	Division 45 Industry-Specific Manufacturing Equipment
FACILITY SERVICES SUBGROUP	*Division 46 Reserved*
Division 20 Reserved	*Division 47 Reserved*
Division 21 Fire Suppression	Division 48 Electrical Power Generation
Division 22 Plumbing	*Division 49 Reserved*
Division 23 Heating, Ventilating, and Air Conditioning	

RS Means (2004) assembly numbering system. RS Means' primary business is research, analysis, and reporting on construction costs. Its assembly taxonomic system is therefore designed for use in construction (and repair) cost estimation. The assembly numbering system is an extension of the UNIFORMAT-II 5-digit system up to level 3, beyond which RS Means adds an additional 3-digit major classification and a final four-digit line number. Despite the detail, the taxonomic groups are testable, and much of the detail simply provides cost information about modest variations between similar assembly types. For example, RS Means provides cost information about 42 versions of drywall partition on metal stud framing. The taxonomic groups are clearly defined and collectively exhaustive, and with an important limitation discussed below, can be reasonably expected to share common fragility functions. Because of the detail and emphasis on cost, this system is highly amenable to assessing consequences. Its hierarchical

structure make it collapsible. RS Means is familiar to contractors and engineers. The major limitations of this taxonomic system are fourfold: (1) its groups do not distinguish some features of seismic resistance, such as the presence of bracing in sprinkler lines or anchorage in floor-mounted electrical equipment; (2) the system is very large, occupying more than 500 pages, with much of the detail irrelevant to seismic performance; (3) to duplicate this extensive taxonomy would require copyright or other agreements that RS Means has expressed an unwillingness to arrange (Miranda 2005); and (4) to use RS Means' taxonomy would tie PBEE to a costly, single-source publication.

RS Means (2000) component numbering system. This document provides unit costs for repair and remodeling, along with greater detail than the RS Means' (2004) assembly cost manual on construction crew productivity and therefore repair duration. The numbering system is based on the familiar CSI MasterFormat, rather than UNIFORMAT-II as in the assembly-numbering system. The taxonomy is clearly defined, collectively exhaustive, and fine enough (with an important limitation noted below) to be testable, amenable to the assessment of consequences (particular because of the cost and duration data), collapsible, and have taxonomic groups that share common fragility functions. As with the RS Means assembly-numbering system, the major limitations of this taxonomic system are that its groups do not distinguish some features of seismic resistance, is very large (with most of the detail irrelevant to seismic performance), and raises issues of copyrights and high cost.

FRAGILITY DATA

It is worthwhile at this point to review a sample of important fragility tests, surveys, and post-earthquake reconnaissance reports because they highlight features that distinguish differences in seismic performance. A feature of a common damageable component that makes a material difference in damageability should be reflected in the taxonomy. It is beyond the present scope of work to perform an exhaustive literature review of the fragility of all nonstructural components, but a brief review is presented here of analytical and reconnaissance literature about key nonstructural components that commonly contribute to losses.

Tests and surveys reviewed here include investigations into the performance of nonstructural partitions by Pardoen et al. (2000), glazing by Sucuoglu and Vallabhan (1997), commercial and industrial mechanical and electrical equipment by Swan and Kassawara (1998), building service

equipment by Johnson et al. (1999), household property by Saeki et al. (2000), small laboratory equipment by Hutchinson (Comerio 2004), and modular office furniture by Filiatrault (1991).

Nonstructural partitions. Pardoen et al. (2000) performed racking tests of a variety of architectural wall systems with various finish materials, framing system, and fasteners. They found that stucco-wall yield displacement (associated with onset of damage) can differ from that of gypsum wallboard by a factor of 3, and from plywood and oriented strandboard by a factor of 10; hence the taxonomy must distinguish between finish materials on nonstructural walls. Gypsum wallboard of 5/8-in thickness was observed to have 60% greater ultimate drift capacity than ½-in wallboard, so wallboard thickness matters to fragility, and presumably sheathing thickness in general matters. (The authors tested nearly constant thicknesses of wood sheathing, so little can be observed from their data about the importance of wood-sheathing thickness on fragility.) Stucco-wall yield displacements differ by a factor of 2 depending on whether the connectors are furring nails or staples, so connectors matter.

Glazing. Limited racking or shake-table tests have been performed of glazing. Examples include Pantelides and Behr (1994), Behr et al. (1995) and Behr and Worrell (1998). Sucuoglu and Vallabhan (1997) present a useful theoretical examination of the fragility of window glass during earthquakes that is more generally applicable, although it is a deterministic, not probabilistic, model. Using their model, one finds that, for floating glass (i.e., with flexible support to the glass within the frame), the chief parameters affecting glazing fracture are glass width, height, the gap between the glass and the frame, and rounded glass corners, each of which, within reasonable bounds, can increase or decrease drift capacity by at least ± 50%. Smaller panes and ones with greater gaps are more rugged. Pane thickness, tensile strength and Young's modulus have more modest effect on glazing capacity, affecting drift capacity by less than 20%.

Laboratory equipment. Hutchinson performed shake-table tests of a variety of laboratory equipment, measuring permanent displacement of objects of various size and base friction, such as computers, microscopes, glassware, etc. (Comerio 2004). In the same publication, the present author analyzed the displacement results to determine the features that matter to whether the objects would slide off a countertop or shelf in an earthquake. For these common laboratory objects, two features matter most to sliding off: base friction and location. It seems likely that common restraint measures such as shelf lips also matter, but these were not tested. Base friction

was divided into two groups, low (coefficient of static friction less than 0.5) and high (greater than 0.5), which essentially means that if the interface between object and counter or shelf includes rubber, then the base friction is high; otherwise, it is low. Location was divided into countertop and shelf, the important distinction being the distance the object must slide before sliding off. A third and fourth parameter—weight and height above floor—do not matter for sliding off, but may matter for consequent injuries. Weight was categorized as low (less than 20 lb), medium (20-400 lb), and high (greater than 400 lb), based on the judgment of consultants who contributed to the study. For present purposes, it seems adequate to include taxonomic groups to break out laboratory equipment and other contents by location (countertop or shelf), base friction (low or high), two categories of weight (≤ 20 lb or > 20 lb), and for shelved items, two categories of height: low (≤ 4 ft above the finished floor) or high (> 4 ft), for a total of 12 groups.

Swan and Kassawara (1998). These authors describe a database of the observed performance of 20 categories of mechanical, electrical, and plumbing equipment in commercial and industrial facilities in 25 earthquakes. The database was compiled in collaboration with the Electric Power Research Institute. The authors also present a methodology for developing fragility functions based on observed performance, as well as the derived fragility function for each category of components. (Here, the fragility functions describe the probability that the equipment will fail to operate after an earthquake, as a function of peak base acceleration.) The authors describe installation conditions that make a material difference in component fragility. This is important: for several of these categories of equipment, seismic installation condition can be described as a binary feature that can be used to define the category of equipment. That is, some components can be said either to be installed to resist earthquakes, or not installed for seismic resistance, based on the post-earthquake observation of several thousand pieces of commercial and industrial equipment. That is not to say that all nonstructural or other building components can be defined as either seismically installed or not, merely that *some* categories can.

International Code Council (2000). The International Building Code addresses nonstructural components through design requirements tailored to different component categories. Its table 1621.2 distinguishes 13 categories of architectural components or elements, each with up to three subcategories (see Table 2). Furthermore, walls and finishes are segregated by fire-resistance rating. A variety of fire-protection systems, smoke-protection system, and their components are defined. Several categories of glazing are addressed. Gypsum board, plaster, and stucco are

addressed. Mechanical, electrical, and plumbing systems are addressed by other codes. There is brief discussion of elevators and conveying systems and their components.

Johnson et al. (1999). These authors offer a tool to estimate and manage the seismic reliability of equipment systems, based on a detailed examination of the system components, and using a simplified logic-tree analysis of the system. The methodology produces a "seismic score" for an overall equipment system, which relates to the annual probability of the equipment system failing to perform its required function. Individual equipment components are assessed using a set of standard, 2-page, multiple-choice forms, one for each of 37 component types. The forms allow the analyst to estimate the seismic reliability of the component, considering the type of component, the seismic hazard at the site, the location of the component within the building, and its installation conditions such as adequacy of seismic restraint and potential for interaction with other components. The scores are then used to assess the reliability of the overall equipment system. The forms offer a pre-established taxonomy of components and of common installation conditions and deficiencies. As in Swan and Kassawara, these authors have defined discrete conditions that distinguish seismically resistant equipment from otherwise. These discrete conditions can be reflected in a taxonomy that has different taxonomic groups to reflect conditions of seismic installation.

Saeki et al. (2000). These authors present data on household property loss resulting from the 1995 Kobe earthquake. The data come from 965 questionnaires returned by insurance-company employees living in the Hyogo and Osaka prefectures. Questions about household property address ownership of and damage to 10 categories of contents: six categories of durable possessions such as furniture, appliances, and electronics; and four categories of non-durables such as curtains, tableware, and clothing. The authors performed regression analyses to calculate the parameters of fragility functions for each category of household contents. The most commonly damaged components were tableware, which commonly toppled or fell to the floor at JMA intensities around 5. The most rugged components were heaters and coolers, which on average experienced damage only when subjected to JMA $\geq$ 7.25.

Table 8. Taxonomy of household contents by Saeki et al. (2000)

Type		Household property	
Durable possessions	A	Large self-standing furniture mainly used for storage (overturning)	Chests, bookshelves, and cupboards
	B	Household electrical appliances (overturning)	Electric refrigerators and washing machines
	C	Household electrical appliances (falling to the floor, toppling over)	Microwave ovens
	D	Household entertainment equipment (falling to the floor, toppling over)	Audiovisual equipment, personal computers, telecommunications equipment, and musical instruments
	E	Floor-standing furniture (crushing)	Dining tables, chairs, living room furniture, and cooking stoves
	F	Heaters and coolers (crushing, overturning)	Air conditioners and heaters
Non-durable possessions	G	Indoor accessories and miscellaneous items (crushing)	Curtains, sliding doors and screens, health and medical equipment, sporting goods, bags, shoes, *Tatami* mats, and carpets
	H	Tableware (falling to the floor, toppling over)	Tableware
	I	Home entertainment items, miscellaneous items (falling to the floor, toppling over)	Clocks, cameras, lighting fixtures, records, CDs, miscellaneous items, and toys
	J	Clothing and bedclothes (physically damaged or contaminated by glass or other foreign matter)	Clothing and bedclothes

Modular office furniture. Filiatrault (1991) reports on shake-table tests of freestanding modular office furniture. Despite tests with excitation up to 5%-damped spectral acceleration up to 1.2g, no damage or overturning of the furniture occurred. EERI (1995) documents at least one case of partial-height office partitions overturning, but its photo does not suggest that injuries occurred as a consequence or that the partitions could not simply be stood back up without repair. This suggests that modular office furniture is relatively rugged, and at present requires no differentiation between varieties in a nonstructural component taxonomy.

POST-EARTHQUAKE RECONNAISSANCE

A brief literature review was performed of post-earthquake reconnaissance, to identify important distinctions that should be reflected in the taxonomy, but where fragility and loss data may still need to be compiled. The review identifies features of nonstructural components that seem to matter for seismic performance, but that are not reflected in the NISTIR 6389 taxonomy. Documents include EERI's (1995) Northridge Earthquake Reconnaissance Report, EERI's (1990) Loma Prieta Earthquake Reconnaissance Report, SEAOC's (1991) Loma Prieta Earthquake reconnaissance report, and EERI's (1984) Coalinga Earthquake Reconnaissance Report. A review of these documents suggest the following important distinctions should be reflected in the taxonomy:

Windows. Lowrise storefront windows with annealed glass, when broken, have sharper edges and are therefore more likely to cause injuries than lowrise storefront windows with tempered, wired, or laminated glass, or glass with shatter-resistant film. Similarly, highrise curtain-wall systems with annealed glass are more dangerous than highrise curtain-wall systems with tempered, wired, or laminated glass, or glass with shatter-resistant film. There is also evidence that glazing with silicone sealant along one or more edges is less likely to be damaged than some glazing systems with roll-in vinyl gaskets or without edge blocks or adequate edge bite; this distinction might be useful in the future.

Suspended ceilings. Suspended ceilings lacking either diagonal braces, compression struts or both appear to be more fragile than suspended ceilings with braces and compression struts.

Elevators. Elevator counterweights tended to derail and render the elevator unusable and require repair; therefore traction passenger elevators should be distinguished from hydraulic passenger elevators, which do not have counterweights. Similarly, traction freight elevators should be distinguished from hydraulic freight elevators. (Passenger versus freight may be irrelevant for earthquake engineering purposes, but the two uses are distinguished at level 4 of NISTIR 6389.)

Concrete block fences. Non-engineered concrete block freestanding walls show greater likelihood of damage than engineered concrete block freestanding walls.

Fire sprinklers. Fire sprinklers that are not compliant with NFPA-13 (1991) are probably more fragile than sprinklers that do comply. Although it is not mentioned in EERI (1995), it is also probably important to distinguish automatic sprinklers (whose lines are charged, that is, filled with water) from pre-action or deluge systems whose lines are dry until a valve opens, and from halon or other non-water-based fire-suppression systems, whose discharge does not damage electronics. Four groups are therefore suggested: automatic sprinklers that are noncompliant with NFPA-13 (1991); automatic sprinklers that are compliant with NFPA-13 (1991); pre-action or deluge sprinklers; and halon or other non-water-based fire-suppression systems.

Heavy cladding. Brick masonry veneer without ties to the supporting wall tends to be far more fragile than brick masonry veneer that is tied to the supporting wall. Similarly, stone veneer without ties to the supporting wall, including stone veneer attached with mortar spots, should be distinguished from stone veneer tied to the supporting wall.

Interior finishes. There appears to be significant differences either in fragility or repair cost for paint on interior partitions, ceramic tile veneer over interior partitions, wallpaper on interior partitions, and vinyl wall coverings.

Roofing tiles. Concrete, clay, and slate roofing tiles that are not individually fastened to the roof sheathing tended to experience damage in the Northridge earthquake and should be distinguished from concrete, clay, and slate roofing tiles that are individually fastened to the roof sheathing. Because of their greater potential to cause injury, heavy tiles should also be distinguished from lightweight roofing, including built-up roofing, single-ply membrane roofs, corrugated roofing, formed metal roofing, and wood, asphalt, and mineral-fiber shingles. Different varieties of lightweight roofing are not distinguished here because the distinctions between them do not appear strongly relevant to their seismic resistance or to the consequences of damage, although such distinctions could be made in the future if appropriate.

Chimneys. Unreinforced brick chimneys commonly break off at the roof line; these should be distinguished from reinforced masonry and precast reinforced concrete chimneys, and from lightweight (insulated metal-lined) flues in woodframe chimneys.

Contents. Household contents and other countertop and shelved contents are categorized as discussed above. Library shelving not braced to the building frame should be distinguished from library shelving that is braced to the building frame. Contents in cabinets without positive mechanical or strong magnetic catches appear more likely to fall out than contents of cabinets with positive mechanical or strong magnetic catches. An additional consideration for shelved contents is that the use of bungy cords and mechanical restraint appears to be somewhat effective in preventing contents from sliding off; one additional category is therefore included: mechanically restrained light contents and light contents on shelves with bungy-cord or spring-mounted wire restraint. A potentially important issue not address here is the distinction between chemicals that, if spilled, represent a health threat, and other contents.

Lighting fixtures. Lay-in fluorescent lighting fixtures without two or more slack safety wires probably pose a greater collapse and safety risk than lay-in fluorescent lighting fixtures with two or more slack safety wires. Similarly, experience in schools suggests that stem-hung pendant fluorescent fixtures without safety wires in the stems pose a greater collapse and safety risk than stem-hung pendant fluorescent fixtures with safety wires in the stems, and that high-intensity-discharge gas vapor lights can also fall.

PROPOSED TAXONOMIC SYSTEM

CONCLUSIONS REGARDING EXISTING TAXONOMIES

Table 9 summarizes the taxonomies reviewed here and the degree to which they offer the desired features. Column headings list the objectives; rows list the existing systems. Each system is rated for how well it meets each objective.

Table 9. Adequacy of existing taxonomic systems to meet stated objectives.

	1. Clear definitions	2. Collectively exhaustive	3. Common fragility functions	4. Testable	5. Distinguishes performance	6. Simple	7. Assessment of consequences	8. Collapsible	9. Flexible	10. Familiar
IBC 2000; ASCE 7-05	◐	●	●	●	●	○	●	●	◐	○
HAZUS	○	◐	○	◐	●	○	○	●	●	○
Porter (2000)	○	◐	○	○	○	●	○	○	◐	○
Taghavi and Miranda (2003)	○	◐	●	○	●	●	○	○	◐	○
Antaki (2004)	●	●	○	●	○	◐	●	○	●	◐
UNIFORMAT II	◐	○	●	●	●	○	●	○	◐	○
NISTIR 6389 (proposed for use here)	○	○	○	○	●	◐	○	○	◐	○
MasterFormat 04	○	◐	○	○	●	●	○	●	◐	○
RS Means assemblies	○	○	○	○	●	●	○	○	◐	○
RS Means components	○	○	●	○	●	●	○	○	◐	○

○ = true ◐ = somewhat true ● = untrue

None of the existing taxonomies examined here satisfies all ten requirements. Most are clearly defined and would be readily understandable to earthquake engineers. Only four are collectively exhaustive: UNIFORMAT-II, NISTIR 6389 (the proposed extension to UNIFORMAT-II), and the two RS Means numbering systems. Of these, the latter two are too detailed to be practical for present purposes, in addition to having copyright and cost issues that would seem to disqualify them from use. The important differences between UNIFORMAT-II and NISTIR 6389 are that the former is too brief to have common fragility functions or to be testable or amenable to the assessment of consequences.

What remains is NISTIR 6389, which is clearly defined, collectively exhaustive, has groups that are generally small enough to share common fragility functions and to be testable, is fairly simple, is explicitly designed to facilitate the assessment of consequences, appears to be readily

collapsible, and should be readily understood by earthquake engineers. However, it has two important deficiencies for present purposes: it does not distinguish features that are relevant to seismic performance, and no mechanism exists for users to add new taxonomic groups as new knowledge develops.

PROPOSED TAXONOMY AND CONSEQUENCE DATABASE

These deficiencies in NISTIR 6389 could be overcome with two expedients that would probably be required for any taxonomy: First, addition of another level of detail to the classification system—here, a level 5, below the four provided by NISTIR 6389—to reflect seismic installation conditions or other subgroups. Second, the taxonomy would have to be easily expandable and interactive, so that researchers or other future users could add subgroups within the existing taxonomy. For example, if a researcher found through experiment that by subdividing category B2021, windows, by frame gap, pane size, etc., the uncertainty on the fragility of subgroups could be reduced below that of the general category B2021, he or she could create new categories B2021.001, B2021.002, etc., name them, define their fragility functions, repair costs, etc., and make that data available to the research community.

Both expedients could be provided for by creating an online, interactive taxonomy database (with other features, described below). The database would offer queries so that users could interact with tables that list the taxonomic groups as well as their parameters of fragility, repair cost, repair duration, and other consequences such as potential for casualties and impact on post-earthquake occupiability and operability of the facility. Users would be able to look up or add records. Each record could be supplied with a pointer (URL or bibliographic citation) to the source of the parameters. Porter (2000) and Taghavi and Miranda (2003) have already developed prototypes of such a database.

Described in this manuscript is an initial draft of such a database. It contain four tables and one html data-access page. The table named "NISTIR 6389" lists the taxonomic groups through Level 4. This table includes the categories shown in Table 6, plus five new categories of structural steel elements (B1031 through B1035), four of reinforced concrete structural elements (B1041 through B1044), and one category of exterior wall finish (B4041). The layout of this table is shown in Table 10. The second table is named "Taxonomy;" its layout, shown in Table 11, is nearly identical to that of "NISTIR 6389" with the addition of 5^{th}-level extensions. A printout of its contents is included in the appendix of this paper.

Table 10. Layout of database table "NISTIR 6389"

Field Name	Data Type	Description
ID	Autonumber	Table index. Table contains taxonomic groups through Level 4.
Level 1 ID	A1	UNIFORMAT-II Level 1, A through F
Level 1 description	A50	UNIFORMAT-II Level 1 description, e.g., Substructure
Level 2 ID	A3	UNIFORMAT-II Level 2, A10 through F20
Level 2 description	A50	UNIFORMAT-II Level 2 description, e.g., Foundations
Level 3 ID	A5	UNIFORMAT-II Level 3, A1010 through F2020
Level 3 description	A50	UNIFORMAT-II Level 3 description, e.g., Standard Foundations
Level 4 ID	A5	NISTIR 6389 proposed UNIFORMAT-II Level 4, A1011 through F2022
Level 4 description	A50	NISTIR 6389 proposed UNIFORMAT-II Level 4 description, e.g., Wall Foundations
Comment	A50	Comment

Table 11. Layout of database table "Taxonomy"

Field Name	Data Type	Description
ID	Autonumber	Table index. Table contains taxonomic groups through Level 4.
Level 1 ID	A1	UNIFORMAT-II Level 1, A through F
Level 1 description	A50	UNIFORMAT-II Level 1 description, e.g., Substructure
Level 2 ID	A3	UNIFORMAT-II Level 2, A10 through F20
Level 2 description	A50	UNIFORMAT-II Level 2 description, e.g., Foundations
Level 3 ID	A5	UNIFORMAT-II Level 3, A1010 through F2020
Level 3 description	A50	UNIFORMAT-II Level 3 description, e.g., Standard Foundations
Level 4 ID	A5	NISTIR 6389 proposed UNIFORMAT-II Level 4, A1011 through F2022
Level 4 description	A50	NISTIR 6389 proposed UNIFORMAT-II Level 4 description, e.g., Wall Foundations
Level 5 extension	A3	ATC-58 proposed Level 5 extension, 001 through 999
Level 5 ID	A9	ATC-58 proposed Level 5 ID, A1011.001 through F2022.999
Level 5 description	A255	ATC-58 proposed UNIFORMAT-II Level 5 description
RS Means line number	A16	RS Means line number by assembly or component, extended to reflect condition
Comment	A50	Comment

The third table is named "RC." It lists fragility functions and repair-cost distributions by Level-5 taxonomic group, for a modest set of component types. Its layout is detailed in Table 12. The fourth table is named "References." It lists brief citations contained in RC and shows the full bibliographic references for each brief citation. Its layout is detailed in Table 13. The data-access page is an html document that allows one to browse, edit, delete, or insert records into table "RC." An image of the data-access page is shown in Figure 4. Noteworthy features of table "RC," apparent in Figure 4, include the following:

- Brief user-friendly name for each component type, along with a detailed description.
- Table lists both NISTIR 6389 category and to RS Means category, for ease of reference for repair-cost and repair-duration information.

- Fields for fragility-function parameters, including engineering demand parameter (EDP), damage measure (DM), description of repair requirements, form of an idealized probability distribution for fragility function (five are anticipated here), and it parameters.
- Fields for repair-cost distribution and parameters, including cost year (to account for inflation) and 3-digit ZIP Code zone for which the cost is applicable (to account for variation in local construction costs).
- Fields for repair duration in crew-hours, and a field for lead time, meaning days waiting for delivery of materials, which might be relevant for specialty equipment)
- Citation fields for reference to source publications for fragility, cost, and repair-duration data.
- Flags to indicate the quality of the fragility function: a field to indicate whether its basis is experimental, analytical, from earthquake experience, or judgment; another to indicate whether the fragility function has been peer reviewed.

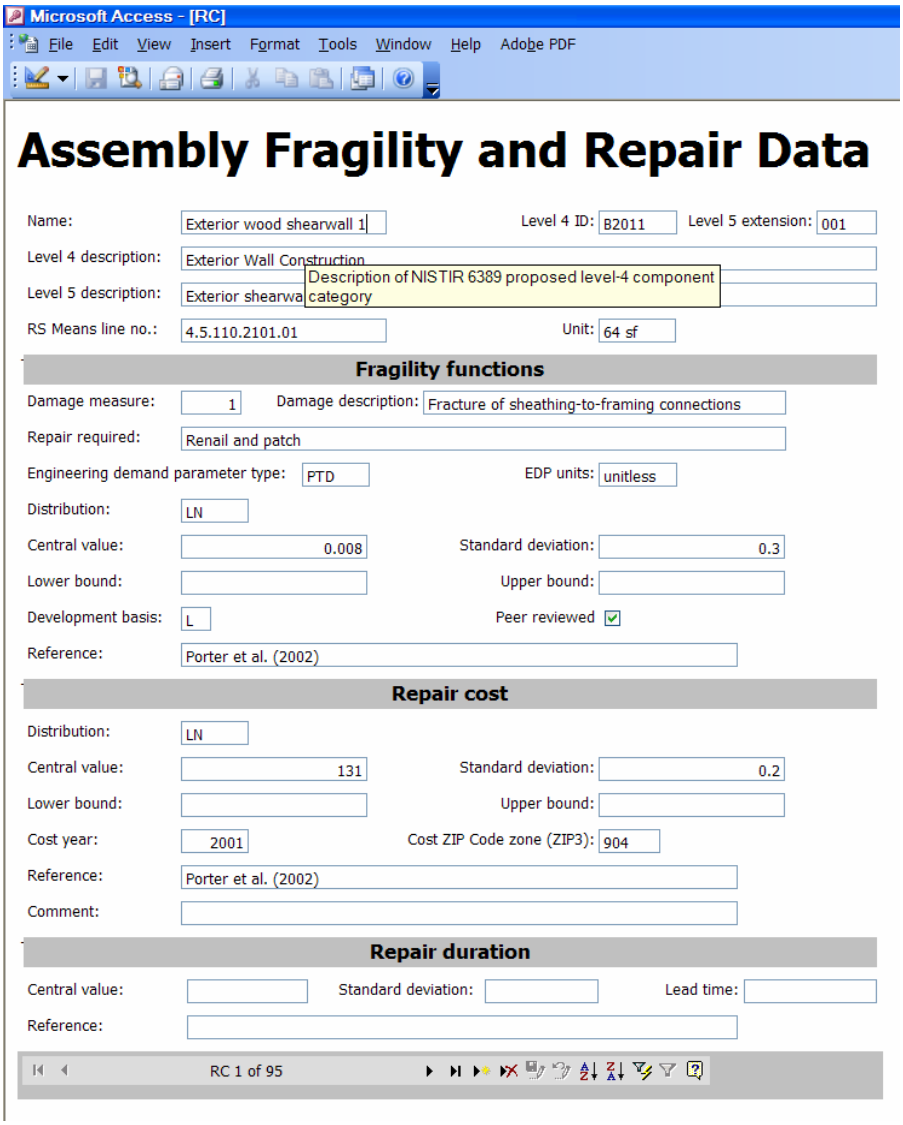

Figure 4. Data access page to taxonomy and fragility database. Note the yellow explanation that appears when the mouse pointer is placed over a data entry box.

For those categories for which the author has fragility, cost, and repair-duration information, these data have been included as well. Fewer than 100 records currently contain fragility function and repair-cost parameters; the remainder are placeholders, showing only name, NISTIR 6389 line number, description, and EDP type. The table named "References" contains citations for all records in RC that have fragility and cost data. It would certainly be desirable to add fragility and repair-cost data compiled by others such as Taghavi and Miranda (2003), and it might be desirable to expand the proposed database to include other consequence characteristics such as life-safety and operational consequences, as those authors did.

Table 12. Layout of database table "RC"

Field Name	Data Type	Description
ID	Autonumber	Table index.Table contains parameters of fragilility functions and unit repair costs
Name	A50	A user-friendly name for the assembly type
RS Means line number	A16	RS Means line number, either by assembly (RS Means's UniFormat extension) or component (MasterFormat extension), extended to reflect seismic condition
Level 4 ID	A4	NISTIR 6389 proposed UNIFORMAT-II Level 4, A1011 through F2022
Level 4 description	A50	NISTIR 6389 proposed UNIFORMAT-II Level 4 description, e.g., Wall Foundations
Level 5 extension	A3	ATC-58 proposed Level 5 extension, 001 through 999
Level 5 description	A255	ATC-58 proposed UNIFORMAT-II Level 5 description
Unit	A12	Unit in which assembly is measured and at which fragility functions and cost distributions apply, e.g., ea, 64 sf, pane, etc.
DM	Integer	Damage state ID within assembly type
DM description	A75	Description of damage state
DM repair description	A50	Description of repair effort
EDP type	A4	Category of EDP most closely related to damage. Choices are peak transient drift ratio (PTD), peak diaphragm acceleration (PDA), modified Park-Ang damage index (PADI), and elastic demand-capacity ratio (DCR)
EDP units	A8	Units in which EDP is measured
Fragility function distribution	A4	Idealized form of capacity distribution (i.e., of fragility function). Choices are lognormal (LN), normal (N), beta (B), uniform (U), and exponential (E)
mFF	Single	Central value of capacity (i.e., of fragility function). For lognormal (LN) or normal (N) distribution, m = median. For beta (B) or exponential (E), m = mean. Not needed for unifirm (U) distribution.
sFF	Single	Dispersion of capacity. For LN, s = logarithmic standard deviation. For N or B, s= standard deviation. Not needed for U or E.
lowerFF	Single	Lower bound of capacity. Only for B and U. Not used for N, LN, or E.
upperFF	Single	Upper bound of capacity. Only for B and U. Not used for N, LN, or E.
Cost distribution	A4	Idealized form of unit-repair-cost distribution. Choices are lognormal (LN), normal (N), beta (B), uniform (U), and exponential (E)
mC	Single	Central value of unit cost. For LN or N distribution, m = median. For B or E distribution, m = mean. Not needed for U distribution.
sC	Single	Dispersion of unit cost. For LN distribution, s = logarithmic standard deviation. For N or B distribution, s = standard deviation. Not needed for U or E.
lowerC	Single	Lower bound of unit cost. Only for B and U distributions. Not used for N, LN, or E.
upperC	Single	Upper bound of unit cost. Only for B and U distributions. Not used for N, LN, or E.
Cost year	Integer	Reference year for cost distribution. Format is YYYY.
Cost ZIP3	A3	Reference location for cost distribution: "Avg" means national average, otherwise use 3-digit ZIP Code zone
Fragility function basis	A1	Basis for fragility function: laboratory experiment (L), analytical (A), earthquake (E), or judgment (J)
Fragility function peer reviewed	Yes/No	Fragility function has been peer reviewed?
Fragility function reference	A50	Brief citation of publication where the capacity distribution (fragility function) is presented
Cost reference	A50	Brief citation of publication of repair-cost distribution is presented
Comment	A255	Explanatory text
mU	Single	Median unit repair duration: crew-hours required to repair one assembly
sU	Single	Standard deviation of unit repair duration (crew-hours).
U0	Single	Mean lead time for delivery of parts (days)
Repair duration reference	A50	Brief citation of publication presenting repair duration
Added by	A4	The initials of the person who added the record
Added date	Date/Time	The date on which the record was added
Last change by	A4	The initials of the person who last changed the record
Last change date	Date/Time	The date on which the record was last modified

Table 13. Layout of database table "References"

Field Name	Data Type	Description
ID	Autonumber	Index. Table contains bibliographic references for fragility functions and cost distributions
Brief reference	A50	Citation from table "RC"
Full reference	Memo	Full bibliographic reference

CONCLUSIONS

A taxonomic system of some kind is required to archive and disseminate damageability and loss data for use in PBEE. A set of 10 criteria for such a taxonomy is presented; the criteria were reviewed and approved by an oversight committee of academics and professionals. Several existing taxonomic systems were reviewed, but none appears to satisfy all 10 requirements. The one that comes closest is a modest extension to the UNIFORMAT-II system, proposed in 1999 by a NIST committee, in the publication NISTIR 6389. NISTIR 6389 proposes the addition of a 4th level to the UNIFORMAT-II system, for the purpose of eliminating some ambiguities in UNIFORMAT-II and to facilitate access to existing cost data. In contrast with the next best existing taxonomic systems (RS Means' assembly and component numbering systems), NISTIR 6389 offers a manageable level of detail and it avoids potentially serious copyright and cost issues that would arise from the use of the proprietary RS Means cost manuals.

It is proposed here to use an extension of the NISTIR 6389 taxonomy for present purposes. The reason for the extension is that the NISTIR 6389 taxonomy has three important shortcomings. First, the taxonomy fails to reflect important differences in seismic installation conditions. Second, it is necessary for present purposes to provide flexibility for future development and additions by PBEE researchers and others. Finally, a few important structural taxonomic groups are not explicitly named, such as beams, columns, braces, connections, and shearwalls.

To overcome these difficulties, three enhancements to NISTIR 6389 are proposed. First, an additional 5th level of detail is added, and a number of level-5 groups are proposed based on readily available fragility and earthquake-reconnaissance data. Future users would be free to define additional level-5 taxonomic groups and their fragility and repair parameters as new research becomes available. Second, it is proposed that the taxonomy be housed within an interactive, online database that also includes fragility data, repair cost and repair-duration data,

and potentially other consequences such as life safety and system and facility operability. Third, nine level-4 taxonomic groups are added to reflect the undifferentiated structural components.

A pilot database is described here. The database is a starting point, containing the NISTIR taxonomy and a table of fragility and cost data compiled by the author over the last few years. However, the content and interactivity of the pilot database are limited. To be practical for use by others, the database will require additional coding. For example, validation rules need to be added to ensure that level-5 taxonomic group numbers shown in the fragility and cost table are not duplicated by different contributors, and that level-4 group numbers in the fragility and cost table are consistent with those defined in NISTIR 6389. Additional security and validation features would probably be required.

Finally, a host would have to be found, and long-term maintenance arranged. The host should be one or more durable institution such as the Applied Technology Council, the Earthquake Engineering Research Institute, the California Institute of Technology's Library system, or the UC Berkeley Earthquake Engineering Research Library. The George E. Brown Network for Earthquake Engineering Simulation (NEES) would be a reasonable consideration if its life were not explicitly limited to 10 yr.

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APPENDIX A: PROPOSED TAXONOMY

The following table contains the proposed taxonomy as developed so far, including the taxonomic groups of NISTIR 6389 (NIST 1999) and some additional subcategories added after a literature review of fragility data or post-earthquake reconnaissance. It is a printout of the table "Taxonomy" outlined in Table 11, modified to fit the page. Three fields are omitted: the index field "ID," RS Means line number, and comments.

Table A-1. Proposed component taxonomy

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
A Substructure	A10 Foundations	A1010 Standard Foundations	A1011 Wall Foundations	A1011.000 Wall Foundations, all
			A1012 Column Foundations, Pile Caps	A1012.000 Column Foundations & Pile Caps, all
			A1013 Perimeter Drainage, Insulation	A1013.000 Perimeter Drainage & Insulation, all
		A1020 Special Foundations	A1021 Pile Foundations	A1021.000 Pile Foundations, all
			A1022 Grade Beams	A1022.000 Grade Beams, all
			A1023 Caissons	A1023.000 Caissons, all
			A1024 Underprinting	A1024.000 Underprinting, all
			A1025 Dewatering	A1025.000 Dewatering, all
			A1026 Raft Foundations	A1026.000 Raft Foundations, all
			A1027 Pressure Injected Grouting	A1027.000 Pressure Injected Grouting, all
			A1029 Other Special Conditions	A1029.000 Other Special Conditions, all
		A1030 Slab on Grade	A1031 Standard Slab on Grade	A1031.000 Standard Slab on Grade, all
			A1032 Structural Slab on Grade	A1032.000 Structural Slab on Grade, all
			A1033 Inclined Slab on Grade	A1033.000 Inclined Slab on Grade, all
			A1034 Trenches, Pits & Bases	A1034.000 Trenches, Pits & Bases, all
			A1035 Under-Slab Drainage & Insulation	A1035.000 Under-Slab Drainage & Insulation, all
	A20 Basement Constr.	A2010 Basement Excavation	A2011 Excavation for Basements	A2011.000 Excavation for Basements, all
			A2012 Structure Back Fill & Compaction	A2012.000 Structure Back Fill & Compaction, all
			A2013 Shoring	A2013.000 Shoring, all
		A2020 Basement Walls	A2021 Basement Wall Construction	A2021.000 Basement Wall Construction, all
			A2022 Moisture Protection	A2022.000 Moisture Protection, all
			A2023 Basement Wall Insulation	A2023.000 Basement Wall Insulation, all
			A2024 Interior Skin	A2024.000 Interior Skin, all
B Shell	B10 Super Structure	B1010 Floor Construction	B1011 Susp. Basement Floor Constr.	B1011.000 Suspended Basement Floors Construction, all
			B1012 Upper Floors Construction	B1012.000 Upper Floors Construction, all
			B1013 Balcony Floors Construction	B1013.000 Balcony Floors Construction, all
			B1014 Ramps	B1014.000 Ramps, all
			B1015 Exterior Stairs and Fire Escapes	B1015.000 Exterior Stairs and Fire Escapes, all
			B1016 Floor Raceway Systems	B1016.000 Floor Raceway Systems, all
			B1019 Other Floor Construction	B1019.000 Other Floor Construction, all
		B1020 Roof Construction	B1021 Flat Roof Construction	B1021.000 Flat Roof Construction, all
			B1022 Pitched Roof Construction	B1022.000 Pitched Roof Construction, all
			B1023 Canopies	B1023.000 Canopies, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			B1029 Other Roof Systems	B1029.000 Other Roof Systems, all
		B1030 Struct. Steel Elements	B1031 Steel Columns	B1031.000 Steel Columns, all
			B1032 Steel Beams	B1032.000 Steel Beams, all
			B1033 Steel Braces	B1033.000 Steel Braces, all
			B1034 Steel Shearwalls	B1034.000 Steel Shearwalls, all
			B1035 Steel Connections	B1035.000 Steel Connections, all
				B1035.001 Pre-Northridge welded-steel moment-frame conn.
		B1040 R/C Struct. Elements	B1041 RC or Composite Columns	B1041.000 Reinf. Concr. or Composite Columns, all
				B1041.001 Nonductile CIP RC column
			B1042 RC or Composite Beams	B1042.000 Reinf. Concr. or Composite Beams, all
				B1042.001 Nonductile CIP RC beam
			B1043 RC or Composite Braces	B1043.000 Reinf. Concr. or Composite Braces, all
			B1044 RC or Composite Shearwall	B1044.000 Reinf. Concr. or Composite Shearwalls, all
	B20 Ext. Enclosure	B2010 Ext. Walls	B2011 Exterior Wall Construction	B2011.000 Exterior Wall Construction, all
				B2011.001 Exterior shearwall, 3/8 C-D ply, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.002 Exterior shearwall, 15/32 C-D ply, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.003 Exterior shearwall, 7/16 OSB, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.004 Exterior wall, no structural sheathing, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.005 Stucco finish, 7/8", 3-5/8" mtl stud, 16"OC
			B2012 Parapets	B2012.000 Parapets, all
			B2013 Exterior Louvers, Screens, Fencing	B2013.000 Exterior Louvers, Screens, and Fencing, all
				B2013.001 Non-engineered concrete block freestanding walls
				B2013.002 Engineered concrete block freestanding walls
			B2014 Exterior Sun Control Devices	B2014.000 Exterior Sun Control Devices, all
			B2015 Balcony Walls & Handrails	B2015.000 Balcony Walls & Handrails, all
			B2016 Exterior Soffits	B2016.000 Exterior Soffits, all
		B2020 Ext. Windows	B2021 Windows	B2021.000 Windows, all
				B2021.001 Window, Al frame, sliding, std glass, 1-25 sf pane
				B2021.002 Window, Al frame, fixed, std glass, 80"x80" pane
				B2021.003 Windows, wood, double hung, standard glass, 3'-1.5"x4'

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				B2021.004 Window, AL frame, sliding, heavy sheet glass, 4'-0x2'-6"x3/16"
			B2022 Curtain Walls	B2022.000 Curtain Walls, all
				B2022.001 Highrise curtain-wall systems with annealed glass
				B2022.002 Highrise curtain-wall systems with tempered, wired, or laminated glass, or glass with shatter-resistant film
			B2023 Storefronts	B2023.000 Storefronts, all
				B2023.001 Lowrise storefront windows with annealed glass
				B2023.002 Lowrise storefront windows with tempered, wired, or laminated glass, or glass with shatter-resistant film
		B2030 Ext. Doors	B2031 Glazed Doors & Entrances	B2031.000 Glazed Doors & Entrances, all
				B2031.001 Doors, sliding, patio, aluminum, std, 6'-0"x6'-8", wood frame, insulated glass
			B2032 Solid Exterior Doors	B2032.000 Solid Exterior Doors, all
			B2033 Revolving Doors	B2033.000 Revolving Doors, all
			B2034 Overhead Doors	B2034.000 Overhead Doors, all
			B2039 Other Doors & Entrances	B2039.000 Other Doors & Entrances, all
	B30 Roofing	B3010 Roof Cover	B3011 Roof Finishes	B3011.000 Roof Finishes, all
				B3011.001 Concrete, clay, and slate roofing tiles that are not individually fastened to the roof sheathing
				B3011.002 Concrete, clay, and slate roofing tiles that are individually fastened to the roof sheathing
				B3011.003 Lightweight roofing
			B3012 Traffic Toppings, Paving Membr.	B3012.000 Traffic Toppings & Paving Membranes, all
			B3013 Roof Insulation & Fill	B3013.000 Roof Insulation & Fill, all
			B3014 Flashings & Trim	B3014.000 Flashings & Trim, all
			B3015 Roof Eaves and Soffits	B3015.000 Roof Eaves and Soffits, all
			B3016 Gutters and Downspouts	B3016.000 Gutters and Downspouts, all
		B3020 Roof Openings	B3021 Glazed Roof Openings	B3021.000 Glazed Roof Openings, all
			B3022 Roof Hatches	B3022.000 Roof Hatches, all
			B3023 Gravity Roof Ventilators	B3023.000 Gravity Roof Ventilators, all
	B40 Ext. Finishes	B4010 Ext. Finish	B4041 Wall Finishes to Exterior	B4041.000 Wall Finishes to Exterior, all
				B4041.001 Paint on exterior stucco or concrete
				B4041.002 Brick masonry veneer w/o ties to the supporting wall
				B4041.003 Brick masonry veneer tied to supporting wall

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				B4041.004 Stone veneer attached with mortar spots
				B4041.005 Stone veneer tied to supporting wall
C Interiors	C10 Int. Construction	C1010 Partitions	C1011 Fixed Partitions	C1011.000 Fixed Partitions, all
				C1011.001 GWB partition, no structural sheathing, 1/2" GWB one side, 2x4, 16" OC
				C1011.002 GWB finish, 1/2", one side, on 2x4, 16"OC
				C1011.003 Interior shearwall, 3/8 C-D ply, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.004 Interior shearwall, 15/32 C-D ply, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.005 Interior sheathing, 3/8 C-D ply, 1/2" GWB finish one side, on 2x4 16" OC
				C1011.006 Interior sheathing, 15/32 C-D ply, 1/2" GWB finish one side, on 2x4, 16" OC
				C1011.007 Interior shearwall, 7/16 OSB, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.008 Interior sheathing, 7/16 OSB, 1/2" GWB finish one side, on 2x4 16" OC
				C1011.009 Drywall finish, 5/8-in., 1 side, on 3-5/8-in metal stud, screws
				C1011.010 Drywall partition, 5/8-in., 1 side, with 3-5/8-in metal stud, screws
			C1012 Demountable Partitions	C1012.000 Demountable Partitions, all
			C1013 Retractable Partitions	C1013.000 Retractable Partitions, all
			C1014 Site Built Toilet Partitions	C1014.000 Site Built Toilet Partitions, all
			C1015 Site Built Compartments Cubicles	C1015.000 Site Built Compartments Cubicles, all
			C1016 Interior Balustrades and Screens	C1016.000 Interior Balustrades and Screens, all
			C1017 Interior Windows & Storefronts	C1017.000 Interior Windows & Storefronts, all
		C1020 Int. Doors	C1021 Interior Doors	C1021.000 Interior Doors, all
			C1022 Interior Door Frames	C1022.000 Interior Door Frames, all
			C1023 Interior Door Hardware	C1023.000 Interior Door Hardware, all
			C1024 Interior Door Wall Opening Elem	C1024.000 Interior Door Wall Opening Elements, all
			C1025 Interior Door Sidelights , Transoms	C1025.000 Interior Door Sidelights & Transoms, all
			C1026 Interior Hatches & Access Doors	C1026.000 Interior Hatches & Access Doors, all
			C1027 Door Painting & Decoration	C1027.000 Door Painting & Decoration, all
		C1030 Fittings	C1031 Fabricated Toilet Partitions	C1031.000 Fabricated Toilet Partitions, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			C1032 Fabricated Compartment , Cubicle	C1032.000 Fabricated Compartments & Cubicles, all
			C1033 Storage Shelving and Lockers	C1033.000 Storage Shelving and Lockers, all
			C1034 Ornamental Metals and Handrails	C1034.000 Ornamental Metals and Handrails, all
			C1035 Identifying Devices	C1035.000 Identifying Devices, all
			C1036 Closet Specialties	C1036.000 Closet Specialties, all
			C1037 General Fittings & Misc. Metals	C1037.000 General Fittings & Misc. Metals, all
	C20 Stairs	C2010 Stairs	C2011 Regular Stairs	C2011.000 Regular Stairs, all
			C2012 Curved Stairs	C2012.000 Curved Stairs, all
			C2013 Spiral Stairs	C2013.000 Spiral Stairs, all
			C2014 Stair Handrails and Balustrades	C2014.000 Stair Handrails and Balustrades, all
		C2020 Stair Finish	C2021 Stair, Tread, and Landing Finishes	C2021.000 Stair, Tread, and Landing Finishes, all
			C2022 Stair Soffit Finishes	C2022.000 Stair Soffit Finishes, all
			C2023 Stair Handrail & Balustrade Finish	C2023.000 Stair Handrail & Balustrade Finishes, all
	C30 Int. Finishes	C3010 Wall Finish	C3011 Wall Finishes to Inside Exterior	C3011.000 Wall Finishes to Inside Exterior, all
				C3011.001 Paint on interior of exterior walls
				C3011.002 Ceramic tile veneer over int. of ext. walls
				C3011.003 Wallpaper on interior of exterior walls
				C3011.004 Vinyl wall coverings on int. of ext. walls
			C3012 Wall Finishes to Interior Walls	C3012.000 Wall Finishes to Interior Walls, all
				C3012.001 Paint on interior concrete, drywall or plastser
				C3012.002 Paint on interior partitions
				C3012.003 Ceramic tile veneer over interior partitions
				C3012.004 Wallpaper on interior partitions
				C3012.005 Vinyl wall coverings on interior partitions
			C3013 Column Finishes	C3013.000 Column Finishes, all
		C3020 Floor Finish	C3021 Floor Toppings	C3021.000 Floor Toppings, all
			C3022 Traffic Membranes	C3022.000 Traffic Membranes, all
			C3023 Hardeners and Sealers	C3023.000 Hardeners and Sealers, all
			C3024 Flooring	C3024.000 Flooring, all
			C3025 Carpeting	C3025.000 Carpeting, all
			C3026 Bases, Curbs and Trim	C3026.000 Bases, Curbs and Trim, all
			C3027 Access Pedastal Flooring	C3027.000 Access Pedastal Flooring, all
		C3030 Ceiling Fin.	C3031 Ceiling Finishes	C3031.000 Ceiling Finishes, all
			C3032 Suspended Ceilings	C3032.000 Suspended Ceilings, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				C3032.001 Lightweight acoustical ceiling 4'-x-2' Al tee-bar grid
				C3032.002 Suspended ceilings w/o diagonal braces, compression struts or both
				C3032.003 Suspended ceilings w/braces, compr. struts
			C3033 Other Ceilings	C3033.000 Other Ceilings, all
D Services	D10 Conveying	D1010 Elevator, Lift	D1011 Passenger Elevators	D1011.000 Passenger Elevators, all
				D1011.001 Traction passenger elevators
				D1011.002 Hydraulic passenger elevators
			D1012 Freight Elevators	D1012.000 Freight Elevators, all
				D1012.001 Traction freight elevators
				D1012.002 Hydraulic freight elevators
			D1013 Lifts	D1013.000 Lifts, all
		D1020 Escalator, Moving Walk	D1021 Escalators	D1021.000 Escalators, all
			D1022 Moving Walks	D1022.000 Moving Walks, all
		D1090 Other Conveying	D1091 Dumbwaiters	D1091.000 Dumbwaiters, all
			D1092 Pneumatic Tube Systems	D1092.000 Pneumatic Tube Systems, all
			D1093 Hoists & Cranes	D1093.000 Hoists & Cranes, all
			D1094 Conveyors	D1094.000 Conveyors, all
			D1095 Chutes	D1095.000 Chutes, all
			D1096 Turntables	D1096.000 Turntables, all
			D1097 Baggage Handling & Loading	D1097.000 Baggage Handling & Loading Systems, all
			D1098 Transportation Systems	D1098.000 Transportation Systems, all
	D20 Plumbing	D2010 Plumbing Fixtures	D2011 Water Closets	D2011.000 Water Closets, all
			D2012 Urinals	D2012.000 Urinals, all
			D2013 Lavatories	D2013.000 Lavatories, all
			D2014 Sinks	D2014.000 Sinks, all
			D2015 Bathtubs	D2015.000 Bathtubs, all
			D2016 Wash Fountains	D2016.000 Wash Fountains, all
			D2017 Showers	D2017.000 Showers, all
			D2018 Drinking Fountains and Coolers	D2018.000 Drinking Fountains and Coolers, all
			D2019 Bidets, Other Plumbing Fixtures	D2019.000 Bidets and Other Plumbing Fixtures, all
		D2020 Domest. Water Distribution	D2021 Cold Water Service	D2021.000 Cold Water Service, all
			D2022 Hot Water Service	D2022.000 Hot Water Service, all
			D2023 Domestic Water Supply Eqpt	D2023.000 Domestic Water Supply Equipment, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
		D2030 Sanitary Waste	D2031 Waste Piping	D2031.000 Waste Piping, all
			D2032 Vent Piping	D2032.000 Vent Piping, all
			D2033 Floor Drains	D2033.000 Floor Drains, all
			D2034 Sanitary Waste Equipment	D2034.000 Sanitary Waste Equipment, all
			D2035 Pipe Insulation	D2035.000 Pipe Insulation, all
		D2040 Rain Water Drainage	D2041 Pipe & Fittings	D2041.000 Pipe & Fittings, all
			D2042 Roof Drains	D2042.000 Roof Drains, all
			D2043 Rainwater Drainage Equipment	D2043.000 Rainwater Drainage Equipment, all
			D2044 Pipe Insulation	D2044.000 Pipe Insulation, all
		D2090 Other Plumbing	D2091 Gas Distribution	D2091.000 Gas Distribution, all
			D2092 Acid Waste Systems	D2092.000 Acid Waste Systems, all
			D2093 Interceptors	D2093.000 Interceptors, all
			D2094 Pool Piping and Equipment	D2094.000 Pool Piping and Equipment, all
			D2095 Decorative Fountain Piping Device	D2095.000 Decorative Fountain Piping Devices, all
			D2099 Other Piping Systems	D2099.000 Other Piping Systems, all
	D30 HVAC	D3010 Energy Supply	D3011 Oil Supply System	D3011.000 Oil Supply System, all
			D3012 Gas Supply System	D3012.000 Gas Supply System, all
			D3013 Coal Supply System	D3013.000 Coal Supply System, all
			D3014 Steam Supply System	D3014.000 Steam Supply System, all
			D3015 Hot Water Supply System	D3015.000 Hot Water Supply System, all
				D3015.001 Electric water heater, resid., 50 gal
			D3016 Solar Energy System	D3016.000 Solar Energy System, all
			D3017 Wind Energy System	D3017.000 Wind Energy System, all
		D3020 Heat Gen. Syst.	D3021 Boilers	D3021.000 Boilers, all
			D3022 Boiler Room Piping, Specialties	D3022.000 Boiler Room Piping & Specialties, all
			D3023 Auxiliary Equipment	D3023.000 Auxiliary Equipment, all
			D3024 Insulation	D3024.000 Insulation, all
		D3030 Cooling Gen. Syst.	D3031 Chilled Water Systems	D3031.000 Chilled Water Systems, all
			D3032 Direct Expansion Systems	D3032.000 Direct Expansion Systems, all
		D3040 Distribution Syst.	D3041 Air Distribution Systems	D3041.000 Air Distribution Systems, all
				D3041.001 Fan
			D3042 Exhaust Ventilation Systems	D3042.000 Exhaust Ventilation Systems, all
				D3042.001 Unreinforced brick chimneys
				D3042.002 Reinforced masonry and precast RC chimneys

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				D3042.003 Insulated metal-lined flue in wood chimneys
			D3043 Steam Distribution Systems	D3043.000 Steam Distribution Systems, all
			D3044 Hot Water Distribution	D3044.000 Hot Water Distribution, all
			D3045 Chilled Water Distribution	D3045.000 Chilled Water Distribution, all
			D3046 Change-over Distribution System	D3046.000 Change-over Distribution System, all
			D3047 Glycol Distribution Systems	D3047.000 Glycol Distribution Systems, all
		D3050 Term.inal, Package Unit	D3051 Terminal Self-Contained Units	D3051.000 Terminal Self-Contained Units, all
			D3052 Package Units	D3052.000 Package Units, all
		D3060 Control,. Instrumentation	D3061 Heating Generating Systems	D3061.000 Heating Generating Systems, all
			D3062 Cooling Generating Systems	D3062.000 Cooling Generating Systems, all
			D3063 Heating/Cooling Air Handling Units	D3063.000 Heating/Cooling Air Handling Units, all
			D3064 Exhaust & Ventilating Systems	D3064.000 Exhaust & Ventilating Systems, all
			D3065 Hoods and Exhaust Systems	D3065.000 Hoods and Exhaust Systems, all
			D3066 Terminal Devices	D3066.000 Terminal Devices, all
			D3067 Energy Monitoring & Control	D3067.000 Energy Monitoring & Control, all
			D3068 Building Automation Systems	D3068.000 Building Automation Systems, all
			D3069 Other Controls & Instrumentation	D3069.000 Other Controls & Instrumentation, all
		D3070 Testing & Balancing	D3071 Piping System Testing & Balancing	D3071.000 Piping System Testing & Balancing, all
			D3072 Air Systems Testing & Balancing	D3072.000 Air Systems Testing & Balancing, all
			D3073 HVAC Commissioning	D3073.000 HVAC Commissioning, all
			D3079 Other Systems Testing, Balancing	D3079.000 Other Systems Testing and Balancing, all
		D3090 Other HVAC	D3091 Special Cooling Systems , Devices	D3091.000 Special Cooling Systems & Devices, all
			D3092 Special Humidity Control	D3092.000 Special Humidity Control, all
			D3093 Dust & Fume Collectors	D3093.000 Dust & Fume Collectors, all
			D3094 Air Curtains	D3094.000 Air Curtains, all
			D3095 Air Purifiers	D3095.000 Air Purifiers, all
			D3096 Paint Spray Booth Ventilation	D3096.000 Paint Spray Booth Ventilation, all
			D3097 General HVAC Items	D3097.000 General Construction Items (HVAC), all
	D40 Fire Prot.	D4010 Sprinklers	D4011 Sprinkler Water Supply	D4011.000 Sprinkler Water Supply, all
				D4011.001 Unbraced automatic sprinklers
				D4011.002 Braced automatic sprinklers
				D4011.003 Automatic sprinklers noncompliant with NFPA-13
				D4011.004 Automatic sprinklers compliant with NFPA-13
				D4011.005 Pre-action or deluge sprinklers

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				D4011.006 Nn-water-based fire-suppression systems
			D4012 Sprinkler Pumping Equipment	D4012.000 Sprinkler Pumping Equipment, all
			D4013 Dry Sprinkler System	D4013.000 Dry Sprinkler System, all
		D4020 Standpipe	D4021 Standpipe Water Supply	D4021.000 Standpipe Water Supply, all
			D4022 Pumping Equipment	D4022.000 Pumping Equipment, all
			D4023 Standpipe Equipment	D4023.000 Standpipe Equipment, all
			D4024 Fire Hose Equipment	D4024.000 Fire Hose Equipment, all
		D4030 Fire Prot. Specialties	D4031 Fire Extinguishers	D4031.000 Fire Extinguishers, all
			D4032 Fire Extinguisher Cabinets	D4032.000 Fire Extinguisher Cabinets, all
		D4090 Other Fire Protection	D4091 Carbon Dioxide Systems	D4091.000 Carbon Dioxide Systems, all
			D4092 Foam Generating Equipment	D4092.000 Foam Generating Equipment, all
			D4093 Clean Agent Systems	D4093.000 Clean Agent Systems, all
			D4094 Dry Chemical System	D4094.000 Dry Chemical System, all
			D4095 Hood & Duct Fire Protection	D4095.000 Hood & Duct Fire Protection, all
	D50 Electrical	D5010 Elect Svc & Distribution	D5011 High Tension Service & Dist.	D5011.000 High Tension Service & Dist., all
				D5011.001 Transformer
				D5011.002 Med voltage switchgear
			D5012 Low Tension Service & Dist.	D5012.000 Low Tension Service & Dist., all
				D5012.001 Unanchored electrical cabinet
				D5012.002 Low voltage switchgear
		D5020 Lighting, Branch Wiring	D5021 Branch Wiring Devices	D5021.000 Branch Wiring Devices, all
			D5022 Lighting Equipment	D5022.000 Lighting Equipment, all
				D5022.001 Lay-in fluorescent lighting fixtures w/o 2+ slack safety wires
				D5022.002 Lay-in fluorescent lighting fixtures w/ 2+ slack safety wires
				D5022.003 Stem-hung pendant fluorescent fixtures w/o safety wires in stem
				D5022.004 Stem-hung pendant fluorescent fixtures w/ safety wires in stem
				D5022.005 High-intensity-discharge gas vapor lights
		D5030 Commun. & Security	D5031 Public Address & Music Systems	D5031.000 Public Address & Music Systems, all
			D5032 Intercommunication & Paging	D5032.000 Intercommunication & Paging Syst., all
			D5033 Telephone Systems	D5033.000 Telephone Systems, all
			D5034 Call Systems	D5034.000 Call Systems, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			D5035 Television Systems	D5035.000 Television Systems, all
			D5036 Clock and Program Systems	D5036.000 Clock and Program Systems, all
			D5037 Fire Alarm Systems	D5037.000 Fire Alarm Systems, all
			D5038 Security and Detection Systems	D5038.000 Security and Detection Systems, all
			D5039 Local Area Networks	D5039.000 Local Area Networks, all
		D5090 Other Elect	D5091 Grounding Systems	D5091.000 Grounding Systems, all
			D5092 Emergency Light & Power	D5092.000 Emergency Light & Power Systems, all
				D5092.001 Diesel generator
			D5093 Floor Raceway Systems	D5093.000 Floor Raceway Systems, all
			D5094 Other Special Systems & Devices	D5094.000 Other Special Systems & Devices, all
				D5094.001 Motor control center
				D5094.002 Unbraced motor installation
			D5095 General Construction Items (Elect.)	D5095.000 General Construction Items (Elect.), all
				D5095.002 Electrical distribution panel
				D5095.003 Inverter
E Eqpt. & Furn.	E10 Equipment	E1010 Commercial Equipment	E1011 Security & Vault Equipment	E1011.000 Security & Vault Equipment, all
			E1012 Teller and Service Equipment	E1012.000 Teller and Service Equipment, all
			E1013 Registration Equipment	E1013.000 Registration Equipment, all
			E1014 Checkroom Equipment	E1014.000 Checkroom Equipment, all
			E1015 Mercantile Equipment	E1015.000 Mercantile Equipment, all
			E1016 Laundry & Dry Cleaning Eqpt	E1016.000 Laundry & Dry Cleaning Equipment, all
			E1017 Vending Equipment	E1017.000 Vending Equipment, all
			E1018 Office Equipment	E1018.000 Office Equipment, all
		E1020 Institutional Equipment	E1021 Ecclesiastical Equipment	E1021.000 Ecclesiastical Equipment, all
			E1022 Library Equipment	E1022.000 Library Equipment, all
			E1023 Theater & Stage Equipment	E1023.000 Theater & Stage Equipment, all
			E1024 Instrumental Equipment	E1024.000 Instrumental Equipment, all
			E1025 Audio-visual Equipment	E1025.000 Audio-visual Equipment, all
			E1026 Detention Equipment	E1026.000 Detention Equipment, all
			E1027 Laboratory Equipment	E1027.000 Laboratory Equipment, all
			E1028 Medical Equipment	E1028.000 Medical Equipment, all
			E1029 Other Institutional Equipment	E1029.000 Other Institutional Equipment, all
		E1030 Vehicular Equipment	E1031 Vehicular Service Equipment	E1031.000 Vehicular Service Equipment, all
			E1032 Parking Control Equipment	E1032.000 Parking Control Equipment, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			E1033 Loading Dock Equipment	E1033.000 Loading Dock Equipment, all
			E1039 Other Vehicular Equipment	E1039.000 Other Vehicular Equipment, all
		E1090 Other Equipment	E1091 Maintenance Equipment	E1091.000 Maintenance Equipment, all
			E1092 Solid Waste Handling Equipment	E1092.000 Solid Waste Handling Equipment, all
			E1093 Food Service Equipment	E1093.000 Food Service Equipment, all
			E1094 Residential Equipment	E1094.000 Residential Equipment, all
			E1095 Unit Kitchens	E1095.000 Unit Kitchens, all
			E1097 Window Washing Equipment	E1097.000 Window Washing Equipment, all
			E1099 Other Equipment	E1099.000 Other Equipment, all
	E20 Furnishings	E2010 Fixed Furnishings	E2011 Fixed Artwork	E2011.000 Fixed Artwork, all
			E2012 Fixed Casework	E2012.000 Fixed Casework, all
			E2013 Blinds and Other Window Treatmt	E2013.000 Blinds and Other Window Treatment, all
			E2014 Fixed Floor Grilles and Mats	E2014.000 Fixed Floor Grilles and Mats, all
			E2015 Fixed Multiple Seating	E2015.000 Fixed Multiple Seating, all
			E2016 Fixed Interior Landscaping	E2016.000 Fixed Interior Landscaping, all
		E2020 Movable Furnishings	E2021 Movable Artwork	E2021.000 Movable Artwork, all
			E2022 Furniture & Accessories	E2022.000 Furniture & Accessories, all
				E2022.001 Large freestanding storage furniture subject to overturning
				E2022.002 Large freestanding household electrical appliances
				E2022.003 Small countertop household electrical appliances
				E2022.004 Household entertainment equipment
				E2022.005 Floor-standing furniture subject to crushing
				E2022.006 Heaters and A/C eqpt subject to crushing or overturning
				E2022.007 Indoor accessories, e.g., curtains, sporting goods, bags
				E2022.008 Tableware
				E2022.009 Small home entertainment items subject to falling
				E2022.010 Clothing etc. subject to contam. by glass, other foreign matter
				E2022.011 Desktop computer system unit and CRT monitor
				E2022.012 Countertop contents, frict. coeff ≤ 0.50, ≤ 20 lb
				E2022.013 Countertop contents, frict. coeff ≤ 0.50, 20-400 lb
				E2022.014 Countertop contents, frict. coeff ≤ 0.50, ≤ 20 lb
				E2022.015 Countertop contents, frict. coeff ≤ 0.50, 20-400 lb
				E2022.016 Shelved contents, frict. coeff ≤ 0.50, ≤ 20 lb, ≤ 4 ft AFF
				E2022.017 Shelved contents, frict. coeff ≤ 0.50, ≤ 20 lb, > 4 ft AFF

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				E2022.018 Shelved contents, frict. coeff ≤ 0.50, 20-400 lb, ≤ 4 ft AFF
				E2022.019 Shelved contents, frict. coeff ≤ 0.50, 20-400 lb, > 4 ft AFF
				E2022.020 Shelved contents, frict. coeff > 0.50, ≤ 20 lb, ≤ 4 ft AFF
				E2022.021 Shelved contents, frict. coeff > 0.50, ≤ 20 lb, > 4 ft AFF
				E2022.022 Shelved contents, frict. coeff > 0.50, 20-400 lb, ≤ 4 ft AFF
				E2022.023 Shelved contents, frict. coeff > 0.50, 20-400 lb, > 4 ft AFF
				E2022.024 Library shelving not braced to the building frame
				E2022.025 Library shelving that is braced to the building frame
				E2022.026 Contents in cabinets w/o mechanical or strong magnetic catch
				E2022.027 Contents in cabinets w/ mechanical or strong magnetic catch
				E2022.028 Mechanically restrained light contents, light contents on shelves w/bungy-cord or spring-mounted wire restraint
			E2023 Movable Rugs and Mats	E2023.000 Movable Rugs and Mats, all
			E2024 Movable Interior Landscaping	E2024.000 Movable Interior Landscaping, all
F Special Constr., Demo	F10 Special Constr.	F1010 Special Structures	F1011 Air Supported Structures	F1011.000 Air Supported Structures, all
			F1012 Pre-engineered Structures	F1012.000 Pre-engineered Structures, all
			F1013 Other Special Structures	F1013.000 Other Special Structures, all
		F1020 Integrated Construction	F1021 Integrated Assemblies	F1021.000 Integrated Assemblies, all
			F1022 Special Purpose Rooms	F1022.000 Special Purpose Rooms, all
			F1023 Other Integrated Construction	F1023.000 Other Integrated Construction, all
		F1030 Special Construction	F1031 Sound, Vibration & Seismic Const.	F1031.000 Sound, Vibration & Seismic Const., all
			F1032 Radiation Protection	F1032.000 Radiation Protection, all
			F1033 Special Security Systems	F1033.000 Special Security Systems, all
			F1034 Vaults	F1034.000 Vaults, all
			F1039 Other Special Construction Syst.	F1039.000 Other Special Construction Systems, all
		F1040 Special Facilities	F1041 Aquatic Facilities	F1041.000 Aquatic Facilities, all
			F1042 Ice Rinks	F1042.000 Ice Rinks, all
			F1043 Site Constructed Incinerators	F1043.000 Site Constructed Incinerators, all
			F1044 Kennels & Animal Shelters	F1044.000 Kennels & Animal Shelters, all
			F1045 Liquid & Gas Storage Tanks	F1045.000 Liquid & Gas Storage Tanks, all
			F1049 Other Special Facilities	F1049.000 Other Special Facilities, all
		F1050 Special Control, Instr.	F1051 Recording Instrumentation	F1051.000 Recording Instrumentation, all
			F1052 Building Automation System	F1052.000 Building Automation System, all
			F1059 Other Special Control, Instruments	F1059.000 Other Special Controls & Instrumentation, all
	F20 Selective	F2010 Building	F2011 Building Interior Demolition	F2011.000 Building Interior Demolition, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
	Demolition	Element Demo.	F2012 Building Exterior Demolition	F2012.000 Building Exterior Demolition, all
		F2020 Hazard Abatement	F2021 Removal of Hazardous Comp.	F2021.000 Removal of Hazardous Components, all
			F2022 Encapsulate Hazardous Comp.	F2022.000 Encapsulation of Hazardous Components, all