LA-13233-MS

LANL Seismic Screening Method for Existing Buildings

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Edited by Ann Mauzy, Group CIC-1
Photocomposition by Paragon Structural Engineering, LLP

LA-13233-MS

UC-906
Issued: January 1997

LANL Seismic Screening Method for Existing Buildings

*Steven L. Dickson**
*Kenneth C. Feller**
Gustavo Otto Fritz de la Orta
Douglas E. Volkman
*Loring A. Wyllie, Jr.***

**Paragon Structural Engineering, LLP.*
***Degenkolb Engineers.*

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

LANL Seismic Screening Method for Existing Buildings

Steven L. Dickson, Kenneth C. Feller, Gustavo Otto Fritz de la Orta,
Douglas E. Volkman, Loring A. Wyllie, Jr.

Abstract

The purpose of the Los Alamos National Laboratory (LANL) Seismic Screening Method is to provide a comprehensive, rational, and inexpensive method for evaluating the relative seismic integrity of a large building inventory using substantial life-safety as the minimum goal. The substantial life-safety goal is deemed to be satisfied if the extent of structural damage or nonstructural component damage does not pose a significant risk to human life.

The screening is limited to Performance Category (PC) -0, -1, and -2 buildings and structures.[a] Because of their higher performance objectives, PC-3 and PC-4 buildings automatically fail the LANL Seismic Screening Method and will be subject to a more detailed seismic analysis. The Laboratory has also designated that PC-0, PC-1, and PC-2 unreinforced masonry bearing wall and masonry infill shear wall buildings fail the LANL Seismic Screening Method because of their historically poor seismic performance or complex behavior. These building types are also recommended for a more detailed seismic analysis.

The results of the LANL Seismic Screening Method are expressed in terms of separate scores for potential configuration or physical hazards (Phase One) and calculated capacity/demand ratios (Phase Two). This two-phase method allows the user to quickly identify buildings that have adequate seismic characteristics and structural capacity and screen them out from further evaluation. The resulting scores also provide a ranking of those buildings found to be inadequate. Thus, buildings not passing the screening can be rationally prioritized for further evaluation.

For the purpose of complying with Executive Order 12941,[b] the buildings failing the LANL Seismic Screening Method are deemed to have seismic deficiencies, and cost estimates for mitigation must be prepared. Mitigation techniques and cost-estimate guidelines are not included in the LANL Seismic Screening Method.

Methodology Background

The original LANL Seismic Screening Method resulted from a collaboration between engineers from LANL's Group FSS-6 Engineering Services Team and Johnson Controls World Services Inc. Design Engineering Group.

The methodology was a hybrid based primarily on seismic evaluation techniques developed in the aftermath of the 1985 Mexico City earthquake[c, d] and the rapid screening techniques of the Federal Emergency Management Agency (FEMA) publication FEMA 154.[e] Objective technical screening criteria were also taken from FEMA 222[f] and the Uniform Building Code (UBC).[g]

The resulting methodology was used to screen 479 LANL buildings and structures, comprising over 7 million square feet of floor space during FY95.[h]

The method used in FY95 was subject to an extensive peer review by Degenkolb Engineers during early FY96. The methodology has been revised to incorporate improvements suggested by LANL FSS-6, Paragon Structural Engineering, and Degenkolb Engineers.[i, j, k, l, m]

METHODOLOGY APPLICATION

The LANL Seismic Screening Method is meant to be applied by experienced structural engineers and trained technicians to determine the relative seismic capabilities of buildings and other structures to resist a specific level of seismic load.

Information is collected from numerous sources, including existing LANL databases, original construction drawing archives, as-built drawings, and field inspections. Relevant screening data are recorded in the LANL seismic database.

Buildings passing both Phase One and Phase Two of the screening are considered to have adequate seismic characteristics to satisfy the minimum goal of substantial life-safety.

Buildings failing either the Phase One or Phase Two screening criteria should undergo a separate, detailed seismic analysis to determine their structural adequacy. Detailed seismic analyses are not a part of the LANL Seismic Screening Method.

An overview of the two-phase screening methodology is presented below:

Phase One Screening

Phase One of the LANL Seismic Screening Method is patterned after FEMA 154.[e] The FEMA 154 "Rapid Visual Screening Procedure" uses a visual sidewalk survey of each building to determine basic building characteristics. Implementation of the FEMA 154 method requires minimal inspector training, no access to the interior spaces of the building, and no review of construction drawings.

The following enhancements to the basic FEMA 154 method have been added to the LANL Phase One screening to take advantage of all available documentation and to remove as much subjectivity as possible from the evaluation criteria:

- All field inspection work is performed by personnel experienced and trained in the fields of structural or civil engineering, architecture, or building construction.
- Construction drawings are reviewed by the inspector and a structural engineer to accurately define and quantify the lateral-force-resisting structural systems.
- All work is directed and reviewed by a structural engineer having experience in design and analysis of buildings for seismic forces.
- The inspector has access to and inspects most interior spaces of the building.
- Building types are identical to the fifteen types defined in FEMA 178,[n] the *NEHRP Handbook for the Seismic Evaluation of Existing Buildings.*
- The Phase One screening uses standardized, quantifiable criteria as the basis for evaluating potential seismic hazards. These criteria are based on requirements of FEMA 222[f] and the UBC.[g]
- A "load path modifier" is introduced to account for incomplete or inadequate lateral load paths.

Buildings receiving a Phase One score of less than 2.0 fail the LANL Seismic Screening Method.

Buildings receiving a passing Phase One score of 2.0 or greater are subject to the Phase Two screening procedure. This procedure yields a capacity/demand ratio based on the LANL site-specific lateral seismic demand coefficient of 0.20.

Phase Two Screening

In Phase Two of the LANL Seismic Screening Method, capacity/demand ratios are calculated for those buildings passing the Phase One screening procedure. This phase of the screening process identifies buildings having inadequate strength to resist a conservative base shear demand coefficient of 0.20.

For all building types, the capacity calculations are based on the basic base shear capacities of various structural elements and materials.[c,d,o] These shear capacity values represent the effective base shear associated with either shear or flexure failure modes. These shear capacity values were used in the seismic evaluation of buildings in Mexico City following the 1985 earthquake. The buildings remaining from the 1985 earthquake that passed this shear capacity evaluation, showed excellent performance during the recent seismic event of September 1995.[p]

In addition, a diaphragm connection capacity is calculated for all buildings. A separate flexural capacity check is also used for those frame-type buildings passing the basic base shear criteria. A braced frame capacity check is also employed. The Phase Two score is determined as the least value of capacity/demand ratio from the above calculations.

Buildings passing Phase One and receiving a passing Phase Two score of 1.0 or greater are considered to possess adequate seismic characteristics to enable substantial life-safety behavior and require no further analysis, except as noted below:

- The PC-3 buildings must satisfy greater seismic demand values and automatically fail the screen. To maintain a complete database, these buildings are catalogued using only the Phase One procedure.
- Steel- and concrete-frame buildings with infill shear walls are known to exhibit complex behavior and automatically fail the screen. These buildings are catalogued using only the Phase One procedure.
- Unreinforced masonry bearing wall buildings exhibit poor seismic behavior and automatically fail the screen. These buildings are catalogued using only the Phase One procedure.
- Buildings that have undergone or are currently undergoing detailed seismic analyses or retrofit are catalogued using the Phase One procedure, but the Phase Two procedure is not performed.

Any building receiving a Phase Two score of less than 1.0 fails the LANL Seismic Screening Method.

DEFINITIONS

Building: Any structure, fully or partially enclosed, that is used for, intended for, or capable of sheltering people or property.

Building Type: One of the fifteen model structure classifications described in FEMA 178:

Type 1	Wood Light Frame
Type 2	Wood Commercial and Industrial
Type 3	Steel Moment Frame
Type 4	Steel Braced Frame
Type 5	Steel Light Frame
Type 6	Steel Frame with Concrete Shear Walls
Type 7	Steel Frame with Infill Shear Walls
Type 8	Concrete Moment Frame
Type 9	Concrete Shear Walls

Type 10	Concrete Frame with Infill Shear Walls
Type 11	Precast/Tilt-Up Concrete Walls with Lightweight Flexible Diaphragm
Type 12	Precast Concrete Frames with Concrete Shear Walls
Type 13	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms
Type 14	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms
Type 15	Unreinforced Masonry Bearing Wall Buildings

Footprint Area: The surface area of the floor nearest the surrounding grade.

IMF: Intermediate Moment Frame of concrete. Typically designed between 1976 and 1985. Not as ductile as SMF, but better than OMF. Positive ductile detailing includes flexure as the governing failure mode, closer-spaced column ties and beam stirrups, and top and bottom beam bars continuous through columns. Insufficient ductile detailing characteristics include column capacities less than beam capacities, column bar splices less than 35 bar diameters, beam bar splices located near beam-to-column joints, beam "truss" bars used as shear reinforcing, and lack of column ties throughout the beam joints.[n]

Modifier: See modification factor

Modification Factor: A measure of the relative impact that certain types of configuration irregularities or physical conditions have on idealized structural performance (varies for each building type).

OMF: Ordinary Moment Frame of concrete. Typically designed before 1976 and characterized by lack of ductile detailing, including shear as the governing failure mode, column capacities less than beam capacities, widely spaced column ties or beam stirrups, column bar splices less than 35 bar diameters, top and bottom beam bars not continuous through columns, beam bar splices located near beam-to-column joints, beam "truss" bars used as shear reinforcing, and lack of column ties throughout the beam joints.[n]

Sector: Any portion of a building satisfying either of the following criteria:

(a) attached additions to the original building that were built at a later date than the original building,

(b) portions of the original facility or additions separated by seismic or expansion joints between the structural systems.

SMF: Special Moment Frame of concrete. Typically designed in 1985 or later. Characterized by special ductile detailing, including flexure as the governing failure mode, column capacities greater than beam capacities, closely spaced column ties and beam stirrups, column bar splices of at least 35 bar diameters, top and bottom beam bars continuous through columns, beam bar splices located away from beam-to-column joints, beam "truss" bars not used as shear reinforcing, and sufficient column ties throughout the beam joints.[n]

Structural Support System: A qualitative classification for buildings based on the type of loads they resist: those resisting gravity loads only, those resisting lateral loads only, and those resisting both gravity and lateral loads.

The distinguishing factor between these systems is whether the failure of the lateral-force-resisting system could cause collapse of the gravity-load-support system.

Reference the structural support systems section of this handbook for descriptions and characteristics of each system.

BASIC CONSIDERATIONS

DETERMINING SECTORS OF A BUILDING

Many buildings at LANL are composed of an original structure having one or more subsequent additions with different design dates. The additions may be of different building types than the original building. The original building may also be divided into discrete structural systems separated by expansion joints. Each subdivided building acts as a separate unit.

Database management and structural evaluation are problematic for the conditions described above. In order to manage data and analyses, such buildings are divided into "sectors."

For the purposes of the LANL Seismic Screening Method, sectors are defined as attached additions to the original building that were built at a later date than the original building, or portions of a building separated by seismic or expansion joints between the structural systems.

Sectors are designated with letters A, B, C, etc., on the field data form. A separate field data form should be used for each sector unless multiple sectors are identical. Each sector is considered separately when assessing a facility. A short description such as "North Wing" is adequate for relatively simple facilities. A key plan sketch should be included on the back of the field data form showing the sector being evaluated.

Sectors separated by expansion joints behave independently during a seismic event. Expansion joints are typically shown on the building's structural drawings. Note the expansion joint dimension shown on the drawings, and compare it with the dimension measured in the field. Record the verified field measurement on the field data form under "d" to consider the effects of adjacency or "pounding."

Attached additions having direct connections with the main building structure do not behave independently from the main structural system. Irregularities in plan or elevation geometry will affect both the original building and the addition. Thus, modification factors for each attached sector will reflect the same irregularities.

Basement walls typically do not contain expansion or seismic joints even if expansion or seismic joints occur between the framing systems above ground. Also, expansion or control joints in exterior finishes, such as roofing, stucco, and masonry veneer, do not always indicate the presence of structural expansion or seismic joints.

DIRECTIONAL CONSIDERATIONS

Most building plan layouts are rectangular or are made up of combined rectangular areas. The structural support systems for these buildings are typically aligned parallel to the primary axes of the building. When reviewing the drawings and during the field inspection, each direction is evaluated separately.

Separate directional evaluations are required for buildings with different building types in each direction. An example is concrete shear walls resisting east-west (E/W) loading with steel braced frames resisting north-south (N/S) loading. Indicate "Sector A, N/S" on one field data form and "Sector A, E/W" on a separate field data form.

Where no direction-specific modification factors are noted, it is permissible to identify both building types on one field data form and note the applicable direction for each one.

Evaluate direction-specific criteria for each direction on the appropriate field data form. A separate score will be recorded for each direction. These results will be reviewed by a structural engineer, and the lowest score will determine the building's final Phase One and Phase Two scores.

Basements versus Aboveground Structures

Many facilities have basements with perimeter concrete walls below grade, while steel or concrete frames are used above grade. Since seismic forces are typically assumed to be transferred to the structure at the ground level, only the above-grade portions of the structure are typically evaluated.

If a structure is completely below grade, a special analysis should be performed to determine the effects of loads that would result from the surrounding soils. This analysis should account for static and dynamic soil forces. A discussion of earthquake-induced soil pressures is provided in Section 11–13 of Reference q.

If the building is built into a slope, some sides of the bottom story may not have solid perimeter walls. If beam-and-column frames or perimeter walls containing large openings are noted, vertical irregularities and torsion problems may exist. Thus, for facilities built into a slope, the lowest story with above-grade exposure will be evaluated. The below-grade portions of the structure should be evaluated for the effects of static and dynamic soil forces as well as the forces from the structure above.

It should be noted that slab-on-grade foundations are not typically part of the structure's lateral-force-resisting system. Thus, minor damage to the slab-on-grade should not be considered as damage to the structural systems. However, slab-on-grade cracking, heaving, or settling may indicate possible differential foundation movement.

Lateral Load Paths

The most essential consideration in evaluating structural integrity is determining whether the building's structural systems provide a complete load path to transfer lateral loads from each area of the structure to the foundation. Lack of a complete lateral load path could cause sudden collapse of the building.

Begin by identifying the building type in each direction. Once this is determined, visualize the path that lateral loads at each level would have to take to reach the foundation. This step is performed in Phase One and relies on drawing review and visual observation. Simple capacity/demand calculations may be required to determine the adequacy of certain load-path components. Following are several important areas to evaluate:[f]

- In-plane continuity and substantial connections between the roof and floor diaphragms and the frames or walls at each level.
- Floor-to-floor continuity between frames or walls that make up the lateral-load-resisting system.
- Substantial flexural capacity at beam-to-column joints in steel or concrete moment frames.
- Substantial bracing and brace connections in steel braced frames.
- Substantial bracing or wall diaphragm capacity in wood or steel stud walls.
- Substantial connections or continuity between structural elements and their supporting foundations.
- Substantial tie-downs, bracing, diaphragm or flexural capacity of the vertical structural elements between the first floor of an elevated building and the ground surface (example: piers or pilasters in a crawl space beneath a modular building).
- Continuous shear walls between the roof and/or floor framing and the foundation.
- On elevated, modular buildings, no individual footings with unmortared or ungrouted masonry pilasters (CMU blocks).
- On elevated, modular buildings, no steel screw jacks or jack stands used as footings.

- On elevated, modular buildings, no individual concrete pad footings set directly on grade without embedment into the ground.

A special modification factor (not included in the FEMA 154 method) shall be applied if a complete lateral load path does not exist. Reference the Structural Scores and Modifiers Table in the Appendix for appropriate values based on building type.

POUNDING: ADJACENT BUILDINGS AND SECTORS

Pounding can occur in response to lateral loads if not enough separation is provided between buildings or additions. The lateral movement of a building or sector is a function of its stiffness.

- Shear wall structural systems exhibit very little lateral displacement when subjected to lateral loads and typically do not create pounding problems. Pounding checks are not performed for bearing wall/shear wall structures, represented by **Type 1** *Wood Light Frame*, **Type 2** *Wood Commercial and Industrial*, **Type 7** *Steel Frame with Infill Shear Walls*, **Type 9** *Concrete Shear Walls*, **Type 10** *Concrete Frame with Infill Shear Walls*, **Type 11** *Precast/Tilt-up Concrete Walls with Light, Flexible Diaphragms*, **Type 13** *Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms*, **Type 14** *Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms*, or **Type 15** *Unreinforced Masonry Bearing Wall Buildings.*

- Moment frame buildings, having less stiffness, may experience relatively large lateral displacements when subjected to lateral loads, creating pounding problems with adjacent buildings or sectors. Braced frame buildings will have intermediate stiffness, with small to moderate lateral displacements and may also create pounding problems. To avoid pounding, building and sector separations must be adequate to allow for lateral displacements. For the purposes of the LANL Seismic Screening Method, only the frame-action **Type 3** *Steel Moment Frame,* **Type 4** *Steel Braced Frame,* **Type 5** *Steel Light Frame,* and **Type 8** *Concrete Moment Frame* building types are susceptible to pounding.[c]

- Certain configurations of **Type 6** *Steel Frame with Concrete Shear Walls* and **Type 12** *Precast Concrete Frames with Concrete Shear Walls* are also susceptible to the effects of pounding.[c] These are limited to configurations where the shear walls are located in the central core of the building, and the frames make up the perimeter.

If any adjacent building or sector has one of these susceptible building types, the separation distance and lowest building height should be recorded on the field data form and pounding calculations performed. Reference the performance modification factors section of this handbook for specific separation-to-height requirements for pounding.

STRUCTURAL SUPPORT SYSTEMS

Reference the Definitions section of this handbook for general criteria regarding structural support systems. The UBC[g] and FEMA 222[f] define four basic types of structural systems capable of resisting lateral loads:

- ***Bearing wall systems*** rely on walls to carry both gravity loads and lateral loads. Older codes refer to this type as a "*box system.*" Failure of the lateral-force-resisting system also compromises the ability of the structure to support gravity loads.

  Building types represented in this category are **Type 1** *Wood Light Frame*, some **Type 2** *Wood Commercial and Industrial*, **Type 9** *Concrete Shear Walls*, **Type 11** *Precast/Tilt-Up Concrete Walls with Lightweight Flexible Diaphragm*, most **Type 12** *Precast Concrete Frames with Concrete Shear Walls*, **Type 13** *Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms*, **Type 14** *Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms*, and **Type 15** *Unreinforced Masonry Bearing Wall Buildings.*

- *Building frame systems* use a complete three-dimensional frame system of beams and columns to support gravity loads and a separate system of nonbearing shear walls, bracing, or infill panels between columns to resist the lateral load.

  Unlike bearing wall systems, the lateral-force-resisting system typically can fail without compromising the ability of the remaining structure to support gravity loads. (This is not always the case as the lack of lateral-force resistance typically could cause the gravity-load frame to displace laterally, resulting in damage or collapse.)

  Building types represented in this category are some **Type 2** *Wood Commercial and Industrial*, **Type 4** *Steel Braced Frame*, **Type 5** *Steel Light Frame* (typical braced end walls and side walls only), most **Type 6** *Steel Frame with Concrete Shear Walls*, **Type 7** *Steel Frame with Infill Shear Walls*, **Type 10** *Concrete Frame with Infill Shear Walls*, and some **Type 12** *Precast Concrete Frames with Concrete Shear Walls*.

- *Moment-resisting frame systems* rely on beam-and-column frames to carry both gravity and lateral loads. No bracing, shear walls or structural infill walls between columns are present. Gypsum-board-sheathed interior partitions are typical. Failure of the lateral-force-resisting system also compromises the ability of the structure to support gravity loads.

  Building types represented in this category are **Type 3** *Steel Moment Frame*, **Type 5** *Steel Light Frame* (typical "rigid frame" bents only), and **Type 8** *Concrete Moment Frame*.

- *Dual systems* use a combination of moment-resisting frames and shear walls (or moment-resisting frames and braced frames) to resist lateral loads in a particular direction. Gravity loads are supported by a complete building frame system. Failure of the lateral-force-resisting systems does not usually compromise the ability of the structure to support gravity loads.

  The only building type that fits into this category is some **Type 6** *Steel Frame with Concrete Shear Walls*. If a Dual System is identified, note the two independent building types, namely **Type 3** *Steel Moment Frame* and **Type 6** *Steel Frame with Concrete Shear Walls*. Separate scores will be calculated for each type, and the lowest score will determine the Phase One results.

BUILDING TYPE IDENTIFICATION

The descriptions found in the structural support systems section of this handbook may not lead to obvious field identification of the proper building type. However, the original building drawings and visual inspection of the facility should provide enough clues for the inspector or structural engineer to determine and field-verify the most appropriate building type to be used on the field data form.

Following are brief descriptions, typical distinguishing characteristics, and special inspection guidelines for each building type:

Building Type 1 *Wood Light Frame*

Type 1 applies to all buildings with wood stud bearing walls. It also applies to buildings with light-gauge steel stud walls or interlocking load-bearing metal panel walls. Lateral loads are transferred through roof and floor diaphragms to braced walls or shear walls.

Several buildings may be attached to form an L- or C-shaped plan. Unless an expansion joint is visible between adjacent roofing and siding, the buildings will act as one unit even if they have separate building numbers. For record keeping purposes, each building will be a separate sector. Record the building numbers or other identifiers for all attached buildings on the field data forms, sketch a plan layout, and explain the geometry in the “Structure Description” section of the form.

Typically, pre-manufactured and modular buildings such as trailers and transportable buildings are this building type.

Some transportables or trailers have perimeter CMU stem walls instead of wood or metal skirting. Typically, these stem walls are not load-bearing and may not have adequate tie-down straps or anchor bolts into the wood framing. Look for CMU block pilasters or steel jack stands beneath the steel skids; these are the load-bearing foundations.

Building Type 2 *Wood Commercial and Industrial*

Type 2 applies primarily to "post-and-beam" structures with few interior walls. Typical lateral-force-resisting systems include wood roof diaphragms with exterior wood shear walls or braced walls.

This building type is not commonly used at LANL and requires special structural detailing to perform adequately. Particular attention must be paid to diaphragm configuration and attachment to the framing, beam-to-column connections, bracing, or shear wall detailing.

Building Type 3 *Steel Moment Frame*

Type 3 buildings are identified by the following characteristics:

- Beam flanges are connected to columns, either directly with welds or with bolted, riveted, or welded end plate or angle connections between each beam flange and the face of the column.
- No bracing is present between columns in the direction being considered. If bracing is present, see **Type 4** *Steel Braced Frame* or **Type 5** *Steel Light Frame.*
- No concrete or masonry shear walls are present parallel to the direction being considered. If parallel masonry or concrete walls are present between steel columns, see **Type 7** *Steel Frame with Infill Shear Walls.* Careful review of the drawings and field conditions should reveal whether masonry walls are structural infill walls or nonload-bearing partitions.

This building type also applies to the "short" direction of steel arch-type corrugated metal buildings such as "Quonset huts". The long direction of a steel arch-type building should be considered as **Type 4** *Steel Braced Frame.*

This building type does not include pre-engineered "metal buildings" such as *Butler®, Atlas®*, or *Robertson®* buildings, although braced frames are typically found on the end walls and side walls of these buildings. Pre-engineered metal buildings are designated **Type 5** *Steel Light Frame.*

This building type does not include tension-support structures or "clamshell" buildings, such as Sprung® structures. These light-weight, aluminum-framed structures are typically covered with a plasticized fabric and most closely resemble **Type 5** *Steel Light Frame* in their behavior during a seismic event.

Building Type 4 *Steel Braced Frame*

Type 4 buildings are identified by the presence of steel angle, rod or cable bracing. Although most older buildings use rod-and-turnbuckle X-bracing, other bracing configurations are possible. Bracing details should be shown on the drawings. Interior finishes will probably prevent visual observation of the bracing in the field, especially for office-occupancy buildings.

This building type also applies to the long direction of steel-arch-type corrugated metal buildings such as Quonset huts. The short direction of a steel-arch-type building should be considered as **Type 3** *Steel Moment Frame.*

Although not commonly used, this building type also applies to buildings with concrete beam-and-column framing employing steel bracing.

This building type does not include pre-engineered "metal buildings" such as *Butler®*, *Atlas®*, or *Robertson®* buildings, although braced frames are typically found on the end walls and side walls of these buildings. Pre-engineered metal buildings are designated **Type 5** *Steel Light Frame.*

Building Type 5 *Steel Light Frame*

Typical **Type 5** buildings are identified by the following characteristics:

- A manufacturer's name plate at the peak of an end wall.
- A specific note on the construction drawings calling for an outside supplier to design and fabricate the building.
- Tapered girders and/or columns (nontapered members may also be used, especially for small buildings).
- Corrugated metal siding and roofing.
- Sag rods and Z- or C-shaped girts in exterior walls.
- Z- or C-shaped roof purlins.
- Usually, no interior columns.

This building type applies to pre-engineered steel buildings (*Butler®*, *Atlas®*, *Robertson®*, etc.). It also applies to tension-supported or "clamshell" buildings, such as Sprung® structures.

As a general rule at LANL, buildings exhibiting **Type 5** characteristics that were designed before 1955 should be classified as either **Type 3** *Steel Moment Frame* or **Type 4** *Steel Braced Frame* and evaluated according to the building type yielding the lowest Phase One score. This precaution is added to the basic FEMA 154 qualifications to account for site-designed and site-built construction that may not meet the controlled design and fabrication guidelines typical of **Type 5** structures designed after 1955.

Building Type 6 *Steel Frame with Concrete Shear Walls*

Type 6 buildings are identified by the following typical characteristics:

- Steel beam-to-column connections are not usually detailed to transfer beam moments resulting from lateral load.
- A substantial floor or roof diaphragm is present to distribute lateral loads to shear walls; this could include standard steel roof deck or concrete over steel floor deck.
- Usually, no bracing is observed in the field or shown on drawings.

The most common application of this building type at LANL consists of a single-story building having a steel roof deck with steel beams supported by interior steel columns. The deck and beams frame into perimeter concrete shear and bearing walls.

Typically, the steel frames resist only gravity loads while the shear walls resist all lateral forces. Shear walls can be located at an elevator core, service core, stairwell, exterior wall, or interior wall.

Some modern buildings use steel moment frames in combination with the shear walls to resist lateral loads. Where moment frames are used, evaluate the building using separate field data sheets for **Type 3** *Steel Moment Frame* and **Type 6.** The lowest Phase One score will govern the final designation.

Where concrete slabs and beams are used instead of steel framing, the structure should be classified as **Type 9** *Concrete Shear Walls.*

Where steel deck and beams are used but no steel columns are present, the structure should be classified as **Type 9** *Concrete Shear Walls.*

Similar building configurations with steel frames and reinforced masonry shear walls are classified as **Type 13** *Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms.*

Building Type 7 *Steel Frame with Infill Shear Walls*

Type 7 buildings can be identified by CMU, brick, concrete panel or clay tile infill walls between exterior or interior columns. These walls may be shown on the original drawings or added during a retrofit project.

This building type applies to all steel frame buildings with structural infill walls, even concrete panels and CMU walls with reinforcing. Typically, these walls are only reinforced to resist wind loads normal to the face of the wall panels, not in-plane forces resulting from frame deflection.

This building type is not commonly used in LANL buildings designed after 1976. It does not apply to frame buildings with masonry veneer or wall panels outside the face of the framing systems. For such systems, refer to **Type 3** *Steel Moment Frame* or **Type 4** *Steel Braced Frame.*

Building Type 8 *Concrete Moment Frame*

Type 8 buildings are identified from the following characteristics:

- Monolithically placed concrete columns supporting girders, beams and slabs.
- No concrete shear walls in the direction of the lateral loads (see **Type 9** *Concrete Shear Walls* if concrete shear walls are present).
- No structural infill walls between columns in the direction of the lateral loads (see **Type 10** *Concrete Frame with Infill Shear Walls* if structural infill walls are present).

Building Type 9 *Concrete Shear Walls*

Type 9 buildings are identified by the following characteristics:

- Concrete walls supporting monolithic concrete floor or roof slabs, with or without concrete beams and girders.
- Concrete walls supporting steel floor or roof framing without the use of any steel columns.
- Monolithic concrete walls having at least 4-inch thickness between pilasters or columns.

This building type must have concrete roof and floor framing. If the predominant load-bearing system consists of steel beams and columns on the interior or perimeter, the structure is **Type 6** *Steel Frame with Concrete Shear Walls.*

Concrete shear walls can be located at an elevator core, service core, stairwell, exterior wall, or interior walls.

If the walls contain integral concrete columns or pilasters located beneath beam- or girder-bearing points, the structure should be classified as **Type 8** *Concrete Moment Frame.* The following guidelines can help distinguish between **Type 6** *Steel Frame with Concrete Shear Walls*, **Type 8** *Concrete Moment Frame* and **Type 9**:

- Steel deck with steel roof or floor beams supported by steel columns are indicative of **Type 6** *Steel Frame with Concrete Shear Walls.*

- Steel deck with or without steel roof or floor beams, but no steel columns, are indicative of **Type 9**.
- Distinct concrete roof or floor beams that frame into concrete columns or pilasters are indicative of **Type 8** *Concrete Moment Frame.*
- Concrete wall thickness less than 4 inches (nonstructural infill walls) between columns or pilasters are indicative of **Type 8** *Concrete Moment Frame.*
- Individual concrete-framed sectors that rely on roof or floor dowels to transfer diaphragm loads across expansion or seismic joints to parallel shear walls are indicative of **Type 8** *Concrete Moment Frame.*

Building Type 10 *Concrete Frame with Infill Shear Walls*

Type 10 buildings can be identified by CMU, brick, concrete panel, or clay tile infill walls between exterior or interior columns. These walls may be shown on the original drawings or added during a retrofit project.

This building type applies to all structural infill walls, even concrete panels and CMU walls with reinforcing. Typically, these walls are only reinforced to resist wind loads normal to the face of the wall panels, not in-plane forces resulting from frame deflection.

This building type is not commonly used in LANL buildings designed after 1976. It does not apply to frame buildings with masonry veneer or wall panels outside the face of the framing systems. For such systems, see **Type 8** *Concrete Moment Frame.*

Building Type 11 *Precast/Tilt-Up Concrete Walls with Lightweight Flexible Diaphragm*

Type 11 buildings can be identified by the following characteristics:

- Precast or individual site-cast concrete exterior wall panel units with steel connector plates or welded "rebar" in vertical joints between panels supporting steel or wood roof deck and beams.
- Wall panels may be solid concrete, precast double-tees, hollow core planks, or sandwich panels (concrete faces with insulating core).
- Wall panels are usually load-bearing. However, they may be non-load-bearing panels with anchors to steel or concrete back-up columns.

This building type does not apply to precast/tilt-up concrete buildings with precast roof or floor framing such as double-tees or hollow-core planks. For such systems, see **Type 12** *Precast Concrete Frames with Concrete Shear Walls.*

Building Type 12 *Precast Concrete Frames with Concrete Shear Walls*

Type 12 buildings are identified by the following characteristics:

- Precast/tilt-up concrete shear and bearing walls supporting precast double-tee or hollow-core plank roof or floor systems.
- Concrete post-and-beam-type framing, consisting of precast concrete beam-and-column assemblies, with either precast or cast-in-place concrete shear walls.

This building type does not include steel or wood roof or floor construction supported by precast bearing walls. If such construction is present, see **Type 11** *Precast/Tilt-up Concrete Walls with Lightweight Flexible Diaphragm.*

Building Type 13 *Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms*

Type 13 buildings are identified by the following characteristics:

- Reinforced and grouted exterior masonry (typically CMU) walls attached to wood or steel roof or floor decks and framing.
- No exterior concrete beams or columns, except for concrete bond beams or concrete framing around wall openings or beneath concentrated loads.
- Steel or concrete interior columns typically used for buildings with large spans and footprints.

Resistance to lateral loads is provided by horizontal joint reinforcing embedded between masonry courses and vertical dowels projecting from the foundation.

In order to qualify as "Reinforced Masonry," wall reinforcing must meet the requirements of the American Concrete Institute (ACI) code ACI 530.[r] For LANL, a minimum amount of reinforcing equal to 0.20 in^2 should be provided around all openings, vertically at each end or corner, and horizontally above and below each diaphragm level. In addition, vertical foundation dowels and steel joint reinforcing equal to 0.0007 times the gross cross-sectional area of the wall must be present. If these minimum requirements are not met, the structure must be classified as a **Type 15** *Unreinforced Masonry Bearing Wall Building.*

If precast concrete roof or floor elements are present, the structure should be classified as **Type 14** *Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms*

Wall reinforcing details and foundation dowels are typically shown on the structural drawings. Record all reinforcing detail information on the field data form.

Building Type 14 *Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms*

Type 14 buildings can be identified by the following characteristics:

- Reinforced and grouted exterior masonry (typically CMU) walls attached to precast concrete double-tee or hollow-core plank roof or floor framing.
- No exterior concrete beams or columns, except for concrete bond beams or concrete framing around wall openings or beneath concentrated loads.

Lateral shear resistance is provided by horizontal joint reinforcing embedded between masonry courses, and vertical dowels projecting from the foundation.

In order to qualify as "reinforced masonry," wall reinforcing must meet the requirements of ACI 530.[r] For LANL, a minimum amount of reinforcing equal to 0.20 in^2 should be provided around all openings, vertically at each end or corner, and horizontally above and below each diaphragm level. In addition, vertical foundation dowels and steel joint reinforcing equal to 0.0007 times the gross cross-sectional area of the wall must be present. If these minimum requirements are not met, the structure must be classified as a **Type 15** *Unreinforced Masonry Bearing Wall Building.*

If steel or wood roof or floor elements are present, the structure should be classified as **Type 13** *Reinforced Masonry Bearing Walls with Lightweight Flexible Diaphragms.*

Wall reinforcing details and foundation dowels are typically shown on the structural drawings. Record all reinforcing detail information on the field data form.

Building Type 15 *Unreinforced Masonry Bearing Wall Buildings*

Structures must be classified as **Type 15** whenever masonry shear walls do not have minimum reinforcing called out on the drawings.[r]

If the minimum amount of reinforcing equal to 0.20 in^2 is not provided around all openings, vertically at each end or corner, and horizontally above and below each diaphragm level, the building is **Type 15**.

In addition, if vertical foundation dowels and steel joint reinforcing equal to 0.0007 times the gross cross-sectional area of the wall are not present, the building is **Type 15**.

Unreinforced Masonry Bearing Wall Buildings may consist of CMU, brick, adobe, natural stone, or any other unit masonry exterior walls supporting any type of roof or floor system and not meeting the minimum reinforcing requirements stated above.

Phase One Screening Procedure

Record Information from Drawing Review

Review the existing construction drawings for each sector to gain an overview of the building's structural systems. Most of the information required on the field data form can be obtained from the drawing review.

Provide a written description of each sector's structural systems including those connected with or adjacent to other portions of the building.

Record the building type on the field data form. See the Building Type Identification section of this handbook for detailed guidance in determining the appropriate building type.

Determine and record the building occupancy type and permanent population on the field data form. Use existing database information if available.

- One exception to the use of "permanent population" data is for "assembly" occupancies such as auditoriums and conference rooms. If a building contains these types of spaces, add the maximum posted room capacity to the permanent population and record this number.
- Another exception to the use of "permanent population" data is for buildings listed as having a population of zero. If the field visit reveals that the building is occupied, inquire as to whether the occupancy is for more than an average of two hours per day. If so, record the number of part-time inhabitants on the field data form.

Record the design date found in the title block of the structural drawings. If review of the structural drawings reveals a specific building code edition, record this information in the "comments" section of the field data form.

Record the range of drawing "C" numbers and sheet numbers on the field data form.

Determine and record the above-grade height and overall plan dimensions of each sector. Calculate and record the "footprint" area. Estimate and record the square footage for each floor level.

Perform Field Inspection to Verify Drawing Information

Perform a visual survey of the building's exterior and interior to gather all remaining information required on the field data form, and verify information recorded during the drawing review.

The inspector shall field-verify that all additions to the building have been accounted for during the drawing review. If drawings for the building or an individual sector are not available, the inspector shall create dimensioned plan, elevation, and detail sketches showing and describing the structural and architectural systems.
The inspector shall carefully note all obvious deviations from the drawings. Especially for such cases, complete descriptions and dimensions are needed to complete both Phase One and Phase Two of the screening.

The inspector shall carefully observe the physical condition of the structural systems. If significant damage or deterioration is found, the inspector shall record descriptions and locations on the field data form.

Following are specific attributes to verify for each building type:

PROCEDURE FOR SPECIFIC BUILDING TYPES

Building Type 1 *Wood Light Frame*

Record the window and door opening locations and dimensions. Large openings in stud walls, such as recessed entryways, long lengths of windows, etc., could cause uneven distribution of lateral stiffness and strength, i.e., a torsion problem. The following information is required to determine the "center of resistance" for torsion calculations:

- If more than 30 percent of any exterior wall area consists of openings, sketch an elevation of the wall, giving overall dimensions and the sizes and approximate locations of all openings. The 30 percent opening "rule of thumb" accounts for substantially decreased rigidity on any one wall. Such stiffness reduction could lead to torsion problems.

- If L-shaped or other configurations are present, check the dimensions of any openings in the interior wall at the junction between the sectors. Include these openings in the above calculation for each sector.

Each trailer or transportable should have an access door into the crawl space beneath the floor. Because the crawl space could be classified as a "confined space," all visual inspections should be made from outside the access door. A flashlight will probably be required.

- If steel skids are used to transfer the loads to the footings, measure and record the distance from the exterior wall to the nearest skid (assume symmetry) and visually estimate the number and spacing of the footings.

- Typical concerns with trailers and transportables are the lack of attachment to the foundation and the inability of individual footings to resist sliding and overturning forces caused by lateral loads. Any of these conditions will trigger the "incomplete load path modifier."

Following are "poor condition" items to look for and record on the field data form:

- wood pads as footings instead of concrete (prohibited by the UBC).[8]

- Deterioration of studs, joists, girders, skids, anchors, etc.

- Erosion beneath footings or around the perimeter of the building, especially if the building is founded on or adjacent to a slope.

- Loose shims (lack of bearing) between skids and piers.

Building Type 2 *Wood Commercial and Industrial*

If the lateral-load-resisting system is shear walls, record the window and door opening locations and dimensions. Large openings in shear walls, such as recessed entryways, long lengths of windows, etc., could cause uneven distribution of lateral stiffness and strength, i.e., a torsion problem. For shear walls, the following information is required to determine the "center of resistance" for torsion calculations:

- If more than 30 percent of any exterior wall area consists of openings, sketch an elevation of the wall, giving overall dimensions and the sizes and approximate locations of all openings. The 30 percent opening "rule of thumb" accounts for substantially decreased rigidity on any one wall. Such stiffness reduction could lead to torsion problems.

- If L-shaped or other configurations are present, check the dimensions of any openings in the interior wall at the junction between the sectors. Include these openings in the above calculation for each sector.

This building type must be engineered for adequate performance during a seismic event. Following are "incomplete load path" conditions to look for and record on the field data form:

- Inadequate ties between the roof or floor diaphragms and the frames.

- Inadequate continuous chord elements around the perimeter of the diaphragms (Unreinforced splices in ledgers, discontinuities in perimeter girders or top plates, etc.).

- Lack of wall bracing or sheathing diaphragms to transmit lateral loads to the foundations.

- Inadequate connections between the columns or walls and the foundations.

Following are "poor condition" items to look for and record on the field data form:

- Deterioration of columns, studs, joists, girders, etc.

- Corrosion of steel bracing or any steel connections.

Building Type 3 *Steel Moment Frame*

This building type relies on the bending resistance of the beams, columns and connections between frame members. Be aware that only certain frames within a building may be moment frames. The locations of moment frames should be designated on the structural framing plans. Beam-to-column connections should also be specifically detailed on the structural drawings or referenced in the notes.

Framing having beam-to-column connections that are able to develop the full capacity of the beams are referred to by the American Institute of Steel Construction, Inc. (AISC) Steel Code[5] as Type 1 or "rigid-frame." This notation may be present in the general notes on the drawings. Type 1 framing is typified by full-penetration welds at beam flanges and "continuity plates" between column flanges at intersecting beam flanges locations. Heavily bolted, full depth end plate beam-to-column connections may also qualify as Type 1 framing.

If noted, Type 3 "semi-rigid framing" may also be classified as **Building Type 3** *Steel Moment Frame*. Type 3 beam-to-column connections are typically designed to resist only a portion of the beam's moment capacity. Typical Type 3 beam flange connections may consist of plates or angles welded between the beam flanges and columns. Type 3 framing may not provide adequate lateral load capacity, especially in buildings designed before 1976.

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify that beam flanges are substantially connected to the columns, either by direct welding, welded plates, welded angles or bolted angles.

- Note whether continuity plates are present in moment frame columns.

- Verify the moment frame beam-and-column sizes and connection details. The adequacy of these components will determine the Phase One "load path modifier" and probably govern the Phase Two capacity of the building. Note all discrepancies between the drawings and field observations on the field data form.

- Verify the number and size of anchor bolts at the moment-resisting columns. All base plates should be grouted or fully flush with the concrete slab or footing, and all anchor bolts should be secured with nuts. Note any crumbled grout, gaps between the base plate and the supporting concrete, missing or loose nuts, or bolt patterns that differ from the drawings.

- Check for incomplete or suspect load path for transfer of lateral loads to the foundation. The lack of substantial beam flange connections to the columns would trigger the "incomplete load path" modifier. See the discussion of beam-to-column connection details above for specific requirements.

Building Type 4 *Steel Braced Frame*

This building type relies on the strength and stability of the bracing members and their connections to the main framing members. Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Check for incomplete or suspect load path for transfer of lateral loads to the foundation.
- Verify and record the size and configuration of all bracing members as well as the brace connections to main members and the foundation.
- Verify that bracing has not been removed or altered from the configurations shown on the drawings.
- Verify that the brace connections are at least as strong as the brace members.
- Where two or more braces are attached to a main member, verify that the centerline of the braces converge at the centerline of the main member.
- If the bracing is accessible, verify that it is "tight." This is a typical problem with rod-and-turnbuckle or cable bracing. If the bracing sags or is easily moved by hand, note this as a "poor condition" entry on the field data sheet.

Building Type 5 *Steel Light Frame*

For a majority of these "pre-engineered" buildings, only architectural and foundation drawings are available, not structural steel framing drawings. Therefore, it is important that all information regarding roof and wall material weights, frame spacing, beam-and-column sizes and column anchorage to the foundations be recorded in the field. As a minimum, verify and record the following information:

- Record the center-to-center spacing and span dimensions of the steel frames.
- Record the column cross-sectional dimensions at the base of the steel columns.
- Estimate the cross-sectional beam-and-column dimensions at their interface.
- Estimate the cross-sectional beam dimensions at the roof ridge.
- Record the weld pattern or size and number of bolts at the beam-to-beam ridge connection.
- Record the weld pattern or size and number of bolts at the beam-to-column connections.
- Record the size and number of column anchor bolts.
- Estimate the size and spacing of the subframe members such as purlins and girts.
- Note the type of roofing, siding, insulation, interior wall and ceiling finishes (ground floor partitions are excluded), and all significant roof-mounted equipment.
- Verify and record the size and configuration of all bracing members as well as the brace connections to main members and the foundation.
- Verify that bracing has not been removed or altered from the configurations shown on the drawings.

- Verify that the brace connections are at least as strong as the brace members.
- Where two or more braces are attached to a main member, verify that the centerline of the braces converge at the centerline of the main member.
- If the bracing is accessible, verify that it is "tight." This is a common problem with rod-and-turnbuckle or cable bracing. If the bracing sags or is easily moved by hand, note this as a "poor condition" entry on the field data sheet.

Check for incomplete or suspect load path for transfer of lateral loads to the foundation. See applicable discussions of connection details for **Type 3** *Steel Moment Frame* and **Type 4** *Steel Braced Frame* above for additional specific guidelines.

Building Type 6 *Steel Frame with Concrete Shear Walls*

The steel frames in these buildings are typically designed to support gravity loads only. Transfer of lateral forces must be accomplished through the steel roof and floor diaphragms and the diaphragm connections to the shear walls. These elements should be the primary focus of the evaluation.

Check for incomplete or suspect load path for transfer of lateral loads to the foundation. Items to verify include adequate reinforcing around all diaphragm openings, no extensive diaphragm openings adjacent to shear walls, and positive connection between the steel framing and the shear walls.

Pay particular attention to the locations of the shear walls. If they are eccentrically located, torsion problems may exist. Reference the "torsion modifier" criteria in the Performance Modification Factors section of this handbook.

Slender shear walls should also be checked for uplift capacity at the foundations. Slender shear walls are defined as those walls having height-to-length ratios greater than or equal to 4 to 1.[f]

Reference **Type 9** *Concrete Shear Walls* for specific criteria for evaluation of the concrete shear walls.

Building Type 7 *Steel Frame with Infill Shear Walls*

This building type exhibits complex behavior when subjected to lateral loading.[i] As a result, for **Type 7** buildings and sectors, all Phase One screening criteria will be recorded, but the Phase Two screening will not be performed. These buildings and sectors automatically fail the screen.

Verify the locations of all openings in the infill panels and that edges of the panels are tight against the steel framing members. Also verify that additional infill panels have not been added since the original design. Record any discrepancies between field observations and the drawings.

For masonry infill, check that the mortar is solid and that no cracks exist in the mortar beds or the masonry itself. Record the locations and general pattern of any cracks. Also record crack patterns and locations in any concrete infill wall panels.

As a check for out-of-plane stability of masonry infill, verify that the wall height/thickness ratios are less than 14 for walls in the top story of a multistory building and less than 20 for all other walls. These limits correspond to Table C7.4.7.1, FEMA 178 for conditions at LANL.[n] Unreinforced masonry infill walls exceeding these limits could be laterally unstable, triggering the "incomplete load path" modifier.

Building Type 8 *Concrete Moment Frame*

This building type relies on the bending resistance of the beams, columns and connections between frame members, similar to **Type 3** *Steel Moment Frame*. Beam-to-column connections should be specifically detailed on the structural drawings.

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify the beam, girder, and column sizes and connection details. The adequacy of these elements will determine the Phase One "benchmark year" and "incomplete load path" modifiers and will govern the Phase Two capacity of the building. Note all discrepancies between the drawings and field observations on the field data form.

- Verify that all concrete or masonry infill or partition walls are isolated from the frames.

- Verify that beams and girders align over the centerlines of the columns.

- Verify that beam and girder reinforcing is continuous through the columns joints.

- Verify that column ties are shown throughout the beam-to-columns joints.

Check for incomplete or suspect load path for transfer of lateral loads to the foundation, including inadequate column dowels to resist possible uplift.

Building Type 9 *Concrete Shear Walls*

Older buildings of this type generally have numerous, relatively thin walls in each direction. However, in buildings where radiation or explosion shielding is a concern, the wall thickness may be greater than required for structural considerations.

Specific items to check are listed below.

- Eccentric locations of the shear walls could cause significant torsion problems.

- Diagonal cracks in shear walls could indicate previous damage resulting from lateral loads and decreased ability to handle future seismic events.

- Shear wall reinforcing spacing greater than 18-inch centers in either direction could indicate inadequate shear strength[n] and should be noted in the "comments" section of the field data form.

- Individual shear walls with height/length ratios greater than 4 to 1 may be subject to overturning,[f] triggering the "incomplete load path" modifier.

- Extensive diaphragm openings adjacent to shear walls or lack of positive diaphragm connections to the shear walls could also trigger the "incomplete load path" modifier.

Building Type 10 *Concrete Frame with Infill Shear Walls*

This building type exhibits complex behavior when subjected to lateral loading.[t] As a result, for **Type 10** buildings and sectors, all Phase One screening criteria will be recorded, but the Phase Two screening will not be performed. These buildings and sectors automatically fail the screen.

Verify the locations of all openings in the infill panels and that edges of the panels are tight against the concrete framing members. Also verify that additional infill panels have not been added since the original design. Record any discrepancies between field observations and the drawings.

For masonry infill, check that the mortar is solid and that no cracks exist in the mortar beds or the masonry itself. Record the locations and general pattern of any cracks. Also record crack patterns and locations in any concrete infill wall panels.

As a check for out-of-plane stability of masonry infill, verify that the wall height/thickness ratios are less than 14 for walls in the top story of a multi-story building and less than 20 for all other walls. These limits correspond to Table C7.4.7.1, FEMA 178 for conditions at LANL.[n] Unreinforced masonry infill walls exceeding these limits could be laterally unstable, triggering the "incomplete load path" modifier.

Building Type 11 *Precast/Tilt-Up Concrete Walls with Lightweight Flexible Diaphragm*

These buildings could have steel deck diaphragms with or without concrete topping or wood deck diaphragms. Both are classified as flexible diaphragms.[n]

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify the locations, number and configurations of the panel-to-panel connectors and the roof diaphragm-to-wall panel connectors, if accessible.
- Verify and record any evidence of cracking around panel connectors.
- Verify that roof or floor framing connections have been detailed for adequate resistance to shear and pullout loads.
- Verify the presence of positive wall panel-to-foundation connections.
- Verify and record the locations, number and size of all openings in the exterior wall panels for evaluation of possible torsional effects.

Building Type 12 *Precast Concrete Frames with Concrete Shear Walls*

These buildings typically have precast concrete diaphragms consisting of double-tees or precast concrete planks with or without concrete topping. Both are classified as rigid diaphragms.[n]

The lateral-force-resisting systems may be cast-in-place concrete shear walls or interconnected precast concrete wall panels.

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify the locations, number and configurations of the panel-to-panel connectors, beam-to-column connectors and the roof diaphragm-to-wall panel connectors, if accessible.
- Verify and record any evidence of cracking around all precast connectors and bearing points.
- Verify that roof or floor framing connections have been detailed for adequate resistance to shear and pullout loads.
- Verify the presence of positive shear wall-to-foundation connections.
- Verify and record the locations, number and size of all openings in the exterior shear walls for evaluation of possible torsional effects.

Building Type 13 *Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms*

These buildings could have steel deck diaphragms with or without concrete topping or wood deck diaphragms. Both are classified as flexible diaphragms.[n]

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify and record the type and thickness of all masonry wall units. Note any specified material strengths, mortar mixing proportions, American Society for Testing and Materials (ASTM) standards, etc. regarding masonry unit type.
- Verify and record the size and spacing of all horizontal and vertical reinforcing.
- Verify and record the spacing of grouted cells in hollow CMU construction.

- Verify and record any grouted cavity wall construction.
- Verify and record all ties or connections between the roof and floor diaphragms and the masonry shear walls.
- Verify continuity in all roof and floor chord members, including continuity across expansion joints and changes in elevation.
- Verify the existence of cross ties between all roof and floor chord members, including continuity across expansion joints and changes in elevation.

Building Type 14 *Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms*

These buildings could have precast double-tee, single-tee or hollow-core plank diaphragms with or without concrete topping. All are classified as rigid diaphragms.[n]

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify and record the type and thickness of all masonry wall units. Note any specified material strengths, mortar mixing proportions, ASTM standards, etc. regarding masonry unit type.
- Verify and record the size and spacing of all horizontal and vertical reinforcing.
- Verify and record the spacing of grouted cells in hollow CMU construction.
- Verify and record any grouted cavity wall construction.
- Verify and record all ties or connections between the roof and floor diaphragms and the masonry shear walls.
- Verify and record the locations and configurations of all diaphragm connectors and the connections between diaphragms and the frame or wall elements.
- Verify continuity in all roof and floor chord members, including continuity across expansion joints and changes in elevation.

Building Type 15 *Unreinforced Masonry Bearing Wall Buildings*

These buildings could have steel deck diaphragms with or without concrete topping, wood deck diaphragms or precast concrete diaphragms.

Following are items requiring verification. Most of this information can be gathered from the structural drawings.

- Verify and record the type and thickness of all masonry wall units. Note any specified material strengths, mortar mixing proportions, ASTM standards, etc. regarding masonry unit type.
- Verify and record the size and spacing of any horizontal and vertical reinforcing.
- Verify and record the spacing of grouted cells in hollow CMU construction.
- Verify and record any grouted cavity wall construction.
- Verify and record all ties or connections between the roof and floor diaphragms and the masonry shear walls.
- Verify continuity in all roof and floor chord members, including continuity across expansion joints and changes in elevation.

- Verify the existence of cross ties between all roof and floor chord members, including continuity across expansion joints and changes in elevation.

- As a check for out-of-plane stability of the masonry walls, verify that the wall height/thickness ratios are less than 14 for walls in the top story of a multistory building and less than 20 for all other walls. These limits correspond to Table C7.4.7.1, FEMA 178 for conditions at LANL.[n] Unreinforced masonry walls exceeding these limits could be laterally unstable, triggering the "incomplete load path" modifier.

PERFORMANCE MODIFICATION FACTORS

Data to be filled in on the field data form includes several performance modification factors as defined below. The values associated with these performance modification factors are combined with the basic score for the appropriate building type to yield a final score for each building or sector.[c]

A sample of the field data form and the values for the Performance Modification Factors are provided in the Appendix. The categories on the field data form correspond to fields in the seismic database.

Circle all applicable conditions on the field data form based on the following criteria. Data from the form will be entered into the database and a Phase One score will be calculated and recorded in the database for each building.

Please note that multiple deficiencies may be found within each modification factor group. An example is *Aspect Ratio > 2:1* and *Reentrant Corners > 15%* may both apply to a specific building or sector. Both deficiencies fall under the "plan irregularity" modification factor group. Where multiple deficiencies within a group occur, circle all deficiencies that apply, but only deduct the modifier value once.

Following are the criteria for determining the performance modification factors:

Incomplete Load Path

This modifier accounts for basic inadequacies in the structural system.

The values for this modifier were chosen to provide a failing Phase One score for those buildings not satisfying the criteria. If gross load path deficiencies exist, the full value of this modifier shall be applied, and the building will fail Phase One.

If a minimal load path can be defined but is suspected of being inadequate, a quick check of the suspect component's capacity should be made by the structural engineer. If the capacity check reveals inadequate strength to resist Phase Two lateral load criteria, up to one-half the full value of this modifier shall be applied to the Phase One score. If other significant configuration problems exist, the building may fail the Phase One screening, and a full Phase Two evaluation will not be performed.

Only the project structural engineer shall determine the degree of load path inadequacy. Reference the "lateral load path" discussion in the Basic Considerations section of this handbook for a summary of general criteria. Reference the Procedures for Specific Building Types in the Phase One screening procedure of this handbook for guidance on application of this modifier for specific building types. As a minimum, verify the structural integrity of the following components.[n]

- Continuity of all roof and floor diaphragms.

- Presence of diaphragm collector elements.

- Diaphragm connections to the frames or shear walls.

- Frame beam-to-column connections.

- Wall bracing or wall diaphragms in braced-frame or stud-wall buildings.

- Shear connections at the foundations.
- Anchorage to resist overturning or uplift at the foundations.

Post Benchmark[e]

This modifier is the only one that adds points to the Phase One "basic score." It is intended to give credit for buildings designed with ductile detailing. The benchmark years shown represent the edition of the UBC where such ductile detailing requirements were first incorporated.[g]

In general, apply this modifier if the building was designed after the year shown. However, the structural engineer shall verify that the actual ductile detailing requirements have been met before assigning this modifier. As a rule, buildings with incomplete or suspect lateral load paths do not qualify for this modifier.[j, m]

Type 1	Wood Light Frame	1949
Type 2	Wood Commercial and Industrial	1949
Type 3	Steel Moment Frame	1976
Type 4	Steel Braced Frame	1988
Type 5	Steel Light Frame	1988
Type 6	Steel Frame with Concrete Shear Wall	1976
Type 8	Concrete Moment Frame	1976
Type 9	Concrete Shear Walls	1976
Types 7/ 10	Concrete or Steel Frame with Infill Shear Walls	*
Type 11	Precast/Tilt-Up Conc. Walls w/ Flexible Diaphragms	1973
Type 12	Precast Concrete Frames w/ Conc. Shear Walls	*
Type 13	RM Bearing Walls w/ Flexible Diaphragms	1976
Type 14	RM Bearing Walls w/ Rigid Diaphragms	1976
Type 15	Unreinforced Masonry Bearing Wall Buildings	*

The * indicates that no modifier can be applied to buildings of this type.[e]

High Rise

Apply modifier if any of the following conditions are present:

Height ≥ 8 Stories	Height ≥ 100 ft	Height ≥ 5L (or 5W)

The 8-story limit is explicit in FEMA 154.[e] The 100-ft limit is based on 8 stories at approximately 12 ft per story.[e] The height-to-length limitation is introduced by LANL to account for relatively slender buildings that have no "floor" levels. The limiting value is based on the overturning equilibrium condition for a 0.20g lateral load acting at mid-height.

Poor Condition

Visually observed or suspected damage to or deterioration of the lateral-force-resisting system. Damage to finishes and nonstructural components shall be noted but shall not trigger this modifier. Some examples include the following:

- Diagonal shear cracks greater than 1.0 mm in width in concrete walls or beams, especially at beam-to-column joints.[n]
- Diagonal shear cracks greater than 1.0 mm in width in load-bearing masonry walls.[n]

- Visible corrosion of reinforcing steel, structural steel or connections.[c, n]
- Wood buildings with extensive rot or pest damage.[c, n]
- Crumbled, missing, or soft mortar joints in masonry shear walls.[c, n]
- Lack of adequate bearing beneath footings (erosion, soil displacement, etc.).
- Vertical differential foundation movement greater than two inches.[c, d]
- Column tilting in excess of two percent as a result of foundation rotation or differential lateral movement.[c, d]

Vertical Irregularity

Apply modifier if any of the following conditions are present:

Vertical Geometric Irregularity

Length of shear walls or frames in one story is 1.3 times the length of those in the adjacent story above or below.[f]

In-Plane Offset

Horizontal offset of vertical load-carrying members in the direction of the load is greater than the length of the vertical member below.[f]

Weak Story

Shear area of lateral-force-resisting system is less than 0.8 times the shear area of the lateral-force-resisting system of the story above.[f]

Weight Irregularity

Weight of any story is greater than 1.5 times the weight of the adjacent story above or below (does not apply to roofs that are *lighter* than the floor below).[f]

Sloped Walls or Columns

The effects of gravity loads are compounded for buildings having sloped walls or columns.[c]

Sloped Grade

Building is founded on a steep hill so that over the width of the building the hill rises at least one story height.[c] This is a less restrictive requirement than FEMA 178, which uses one-half story.[n]

Plan Irregularity

Apply modifier if any of the following conditions are observed (Only applicable for portions of a building that are not separated by a structural expansion joint):

Reentrant Corners

The plan dimension of a projecting sector or wing is greater than 0.15 times the largest plan dimension of the primary portion or sector of the building. The "primary" portion of a building shall be the largest possible rectangular area.[f]

Based on what LANL interprets the FEMA 222 criteria to be, the "largest plan dimension" qualifier has been added to the basic FEMA 222 requirement. This is intended to cover those situations where a long, narrow building has a small addition attached to the long side of the building.

Attached Sector

The footprint area of the attached sector or addition is greater than 0.2 times the main building footprint area.[c, d]

Aspect Ratio

The ratio of building length to width is greater than 2.[c, d] Exception: A significant interior lateral-force-resisting system is provided such that the spacing between lateral-force-resisting components is 2 times the building width or less.[i, j]

Tilt-Up Building Size

The footprint area of a tilt-up or precast frame building (**Types 11** or **12**) is greater than 100,000 square feet.[c] Exception: A significant interior lateral-force-resisting system is provided such that the plan area bounded between lateral-force-resisting systems is 100,000 square feet or less.[i, j]

Diaphragm Discontinuity

The sum of cutout or open areas in any horizontal diaphragm at any story is greater than 0.5 times the gross bounded area of the diaphragm.[f]

Out-of-Plane Offset

Any horizontal offset of columns or walls perpendicular to the direction of applied lateral force.[f] An example is where a bearing wall in an upper story does not line up with the bearing wall(s) in the story below.

Nonparallel System

Shear walls or frames not parallel to or symmetric about the major axes of the building, or columns not oriented parallel to the major axes of the building.[f]

Soft Story

Apply modifier if any of the following conditions are present:

The sum of the lateral stiffnesses of all columns or shear walls in one story ($\Sigma EI/L^3$) is less than 0.7 times the stiffness of the story above or less than 0.80 times the *average* stiffness of the three stories above.[f]

As a guide for typical conditions: If columns are the same size and none are missing at a particular story, then the column length in that story must be less than 1.13 times the column length of the story above. If they are taller, a soft story exists.

Torsion

Apply modifier if the following condition is present:

Preliminary calculations or professional judgment indicate that the horizontal eccentricity between the building's center of mass and its center of resistance is greater than 0.20 times the corresponding building width or length.[n]

Large, Heavy Cladding

Apply modifier if the following condition is present: (only applicable to **Type 3** *Steel Moment Frame*, **Type 8** *Concrete Moment Frame* or **Type 12** *Precast Concrete Frames with Concrete Shear Walls*)

Exterior cladding panels weighing more than 15 pounds per square foot (psf) on frame-type buildings designed before 1976.[c] The 15 psf qualifier was added by LANL to exclude light-weight cladding systems such as exterior insulation and finish systems (EIFS), metal and composite panels, and glazed curtain wall systems.

Short Columns

Apply modifier if any of the following conditions are present: (only applicable to **Type 7** *Steel Frame with Infill Shear Walls*, **Type 8** *Concrete Moment Frame*, **Type 10** *Concrete Frame with Infill Shear Walls*, or **Type 12** *Precast Concrete Frames with Concrete Shear Walls*)

Partial-height structural infill walls have been installed between interior or exterior columns such that $0.15H < h < 0.85H$,[c, n] where H is the original height, and h is the shortened free height of the column. The height qualifiers were added by LANL based on the following reasoning:

> Shortened column heights that are 85 percent of the original height are approximately 60 percent more rigid and would attract proportionately more load. This increased load is slightly more than the reserve column capacity based on the original column design.
>
> Once the column is shortened to only 15 percent of its original height, column shear is extremely higher than the original capacity. However, partial confinement by the infill walls will typically prevent complete collapse of the columns.

Infill walls do not include exterior masonry veneer, which is typically installed outside the exterior face of the structural frames.

Rigidly connected exterior spandrel beams or panels resulting in the column lengths described above have been installed between columns following the initial building construction.

Soil Type

Rigid Soil

Rigid soil is defined as rock of any characteristic or less than 200 feet of stiff to hard clayey soil, medium dense to very dense sandy soil, or moderately firm to hard cemented sands, silts, and silty or clayey sands or gravels directly underlying the foundations. The limiting factor in classification of the above soil consistencies is a standard penetration resistance (N) value of 9 or greater.[f, u]

Medium Soil

Medium soil is defined as deposits of more than 200 feet of stiff to hard clayey soil, medium dense to very dense sandy soil, or moderately firm to hard cemented sands, silts, and silty or clayey sands or gravels directly underlying the foundations. The limiting factor in classification of the above soil consistencies is a standard penetration resistance (N) value of 9 or greater.[f, u]

Soft Soil

Soft soil is defined as 30 feet or more of very soft to medium stiff clayey soil, very loose to loose sandy soil, or very soft to soft cemented sands, silts, and silty or clayey sands or gravels directly underlying the foundations. The limiting factor in classification of the above soil consistencies is a standard penetration resistance (N) value of 8 or less [f, u].

Rigid soil is typical for most buildings at Los Alamos. Buildings founded on piers extending beyond soft or medium soils to the underlying rigid soils should also be classified as bearing on rigid soil.

Pounding

Apply modifier if the following condition is present: This modifier is only applicable if the building under consideration or an adjacent building or sector is **Type 3** *Steel Moment Frame*, **Type 4** *Steel Braced Frame*, **Type 5** *Steel Light Frame*, **Type 6** *Steel Frame with Concrete Shear Walls*, **Type 8** *Concrete Moment Frame*, or **Type 12** *Precast Concrete Frame with Concrete Shear Walls.*

Separation-to-Height Ratio

The minimum separation, d, between any two buildings (or sectors of a building isolated by a structural expansion joint) is less than the following ratios of the lowest building's overall height, H:[c, d]

soft soil	d < 0.008H
medium soil	d < 0.007H
rigid soil	d < 0.006H

Phase Two Screening Procedure

The Phase Two screening procedure will be performed if the Phase One score for a building or sector is 2.0 or greater. The purpose of this procedure is to determine a capacity/demand ratio based on conservative assumptions. This ensures that buildings have adequate strength to resist seismic forces.

All PC-3 buildings, as well as all **Type 7** *Steel Frame with Infill Shear Walls*, **Type 10** *Concrete Frame with Infill Shear Walls*, and **Type 15** *Unreinforced Masonry Bearing Wall Buildings* automatically fail the screen and are not subject to the Phase Two procedure.

Seismic Capacity

Seismic capacity shall be determined at the ground level of the structure and at intermediate levels having substantial changes in lateral load or strength.

The seismic capacity values used at LANL are based primarily on field-determined unit base shear capacity values as summarized below and documented in References c, d and o. All values represent ultimate strength. Supplemental capacity values, where referenced below, are based on References f and n.

Calculating Building Areas

Determine the total square footage of the building roof and each floor level above grade. If certain portions of one floor level are a different type of construction, calculate the areas separately. Floor levels at grade are typically neglected.

Calculate the surface area of each exterior wall above grade. Include allowances for doors and windows. Also determine the surface area of any interior bearing walls or masonry partitions.

Record the plan dimensions of the lateral-force-resisting structural systems. Also record the out-to-out wall dimensions in each direction for shear wall buildings and center-to-center column dimensions in each direction for frame-type buildings. For full-length shear walls, the structure dimension will match the overall building dimension. For partial length shear walls and frame-type building systems, the structure dimension will be less than the overall building dimension.

Complete structural system descriptions and dimensions are needed to adequately define the loads and element capacities.

Calculating Building Weights

Using standard unit weights of construction materials or construction assemblies, calculate the dead loads for each roof, floor, and wall area. The dead load of a representative bay may be determined instead of the total building weight.

Following are some guidelines to use when calculating dead loads:

- Include electrical, mechanical, and miscellaneous loads as appropriate for each roof or floor level. Values may range from a minimum of 5 psf for a storage building roof, to 10 psf for a typical office floor, to 15 psf or more for a laboratory roof with a large number of mechanical units.

  The above values are based on LANL experience.

- Apply a dead load allowance of 10 psf to each floor or roof level. This value can be reduced to 5 psf for certain lightweight buildings.

  These values are intended to account for 25 percent of typical floor live load or 33 percent of roof snow load.[n]

- Include a 10 psf partition load to be applied to the floor area for all office floors.

  This load is added to the floor dead loads and is equal to 50 percent of the 20 psf additional partition dead load specified in the UBC.[g]

Calculating Building Capacity

Only those elements that are part of the lateral-force-resisting system are assumed to contribute to the building capacity.

The building capacity, **R**, should be calculated along each orthogonal axis of the building. Thus, if the building is composed of shear walls, only those walls parallel to the direction of the lateral load are effective.

Similarly, only those moment frames or braced frames that are parallel to the lateral load are effective. Interior columns that are not part of the lateral-force-resisting system do not contribute to building capacity, **R**.

If the building capacity, **R**, is obviously smaller, for instance, in the E/W direction, state that the E/W direction "controls," and do not calculate **R** in the N/S direction.

The building capacity, **R**, is the least value of the following based on the appropriate building type:

Basic Base Shear Capacity for All Building Types (except **Type 7** *Steel Frame with Infill Shear Walls* and **Type 10** *Concrete Frame with Infill Shear Walls)*

Calculate the net cross-sectional area at the base of the vertical structural members, such as shear walls or columns. Multiply the net cross-sectional area by the appropriate unit shear resistance values listed below to obtain the basic base shear capacity.[c,d,o]

Basic Base Shear Capacity

The basic base shear capacity is calculated from the following formula:

$$\textbf{basic base shear capacity} = \Sigma \mathbf{A}_i \mathbf{f}_i \ ,$$

where $\mathbf{A}_i$ is the cross-sectional area at the base of the resisting structural members of material type i measured in square inches , and $\mathbf{f}_i$ is the unit shear capacity of the resisting structural members of material type i measured in pounds per square inch (psi).

Following are a few guidelines for determining the resisting cross-sectional area, A_i, are:

- For steel frames with column base plates on top of the floor slab or foundation, A_{st} is the total cross-sectional area of the steel anchor bolts.
- For steel frames with columns embedded in the floor slab or foundation, A_{st} is the total cross-sectional area of the steel columns.
- For concrete shear walls or concrete columns, A_{cw} or A_{cc} is the gross cross-sectional area of the concrete walls or concrete columns. If precast concrete double-tee shear walls are used, only the flanges are effective in calculating A_{cw}.
- For CMU shear walls, A_{mw} is the net cross-sectional area of the CMU blocks plus any cells containing grout.
- Masonry shear walls must be at least 4" nominal thickness to be effective.[f]

Following are the basic unit shear capacity values, f_i, for steel, masonry, and concrete.[c, d, o] The values for concrete columns in ordinary moment frames have been reduced to account for decreased response coefficients. See the discussion in the following subsection for further information.

Base Shear Capacity	Resisting Member Material Type and Configuration
f_{mw} = 21 psi	net area of masonry units and grouted cells
f_{cw} = 171 psi	concrete wall with no end columns
f_{cw} = 229 psi	concrete wall with column at one end
f_{cw} = 286 psi	concrete wall with columns at both ends
f_{cc} = 62 psi	SMF or IMF: concrete column with $H/h > 10$
f_{cc} = 100 psi	SMF or IMF: concrete column with $6 < H/h \leq 10$
f_{cc} = 143 psi	SMF or IMF: concrete column with $2 < H/h \leq 6$
f_{cc} = 214 psi	SMF or IMF: concrete column with $H/h \leq 2$
f_{cc} = 38 psi	OMF: concrete column with $H/h > 10$
f_{cc} = 62 psi	OMF: concrete column with $6 < H/h \leq 10$
f_{cc} = 88 psi	OMF: concrete column with $2 < H/h \leq 6$
f_{cc} = 132 psi	OMF: concrete column with $H/h \leq 2$
$f_{st} = 0.2F_y$	steel column or anchor bolts (F_y is yield stress, psi)

Note that **h** is the least thickness and **H** is the clear height of the concrete column between slab or beams. If one floor does not have beams that frame into the column on all four sides, **H** is the clear height to the next floor with beams. Also, if partial height infill walls restrict the column, **H** is reduced accordingly.

Diaphragm Connection Capacity for All Building Types

Calculate the least value of diaphragm connection capacity at the attachment points of all applicable horizontal diaphragm levels. This is especially important where additions are attached to existing structures.

All capacity calculations are based on ultimate strength criteria.

Flexural Capacity for Building Type 3 *Steel Moment Frame*, **Type 5** *Steel Light Frame* and **Type 8** *Concrete Moment Frame.*

Calculate the flexural capacity of a typical frame based on overall member capacities and connection strength. Subsections 4.3.5 and 4.3.6 of Reference n shall be used to evaluate the capacities of the columns as shown below.

Calculate the shear associated with flexural capacity, $V_e=2M_{pr}/L$, and compare to the shear capacity of the columns based on the values presented in the table above. M_{pr} is the flexural capacity of the columns using a strength reduction factor, $\phi=1.0$ and an assumed steel yield strength, $f_s=1.25f_y$.[n]

Braced-Frame Capacity for Type 4 *Steel Braced Frame*

Calculate the braced-frame capacity of a typical frame based on overall bracing element capacities and connection strength.

All capacity calculations are based on ultimate strength criteria.

Seismic Demand

The seismic demand is obtained by first estimating the building dead loads. These dead loads are multiplied by a seismic base shear coefficient equal to 0.20 for LANL to obtain the seismic demand.

The base shear coefficient at LANL is 0.20. This value represents the LANL-specific horizontal spectral acceleration (ZC) of 0.52 multiplied by an importance factor (I) of 1.25 for PC-2 buildings and divided by an average response coefficient (R) of 3.25.[v, w]

Type 7 *Steel Frame with Infill Shear Walls*, **Type 10** *Concrete Frame with Infill Shear Walls*, and **Type 15** *Unreinforced Masonry Bearing Wall Buildings* all have response coefficients less than 3.25, but automatically fail the screen. Capacity/demand ratios are not calculated for these buildings.

The base shear coefficient value (ZIC/R) of 0.20 is conservative for all remaining building types except **Type 8** OMF *Concrete Moment Frame* buildings. The actual ZIC/R values for all remaining building types except **Type 8** OMF are bounded by 0.929*(0.20) for the least ductile structural system and 0.406*(0.20) for the most ductile systems.[n]

To maintain conservatism for **Type 8** OMF buildings, the LANL Method uses reductions in the unit shear capacity values, as summarized in the previous subsection. The reduction factor is 62% of the basic value for **Type 8** OMF buildings.

The seismic demand, **V**, is the lateral shear force assumed to act horizontally at a particular level of the building. The load can act in any direction, but only in one direction at a time. The seismic demand, **V**, is calculated as follows:

$$\mathbf{V = 0.20\ \Sigma W},$$

where **ΣW** is the dead load of the building (or representative bay) above the level being considered.

Seismic Capacity/Demand Ratio

The Phase Two score is expressed as a capacity/demand ratio. This ratio is a measure of the building's resistance to a lateral load based on a 0.20g horizontal acceleration. Since the building capacity, **R**, is determined in two directions, two capacity/demand ratios could be calculated. Only the lowest capacity/demand ratio, $\mathbf{S_f}$, will be entered as the Phase Two score into the seismic database.

The capacity/demand ratio, S_r, is calculated:

$$S_r = {}^{R}/_{V}.$$

Enter the Phase Two score on the field data form.

SCORING SUMMARY

PHASE ONE SCORE

The basic score for the applicable building type and the appropriate modifiers will be summed to achieve the Phase One score. The inspector will record the resulting Phase One score on the field data form.

The inspector will proceed based on one of the following Phase One screening results:

Phase One Score ≥ 2.0

Any building with a Phase One score of 2.0 or greater passes Phase One and will be subject to the Phase Two screening procedure. Reference the specific criteria outlined in the Phase Two screening procedure above.

Phase One Score < 2.0

Any building with a Phase One score less than 2.0 fails the LANL Seismic Screening Method. No Phase Two screening procedures will be performed. The inspector's work is complete.

PHASE TWO SCORE

Buildings passing Phase One are subject to the Phase Two screening procedure. The lowest value of the capacity/demand ratio is the Phase Two score. The inspector will record the resulting Phase Two score on the field data form.

Phase Two Score ≥ 1.0

Any building with a Phase Two score of 1.0 or greater passes both phases of the LANL Seismic Screening Method and is considered adequate to provide substantial life-safety for a seismic event. The inspector's work is complete.

Phase Two Score < 1.0

Any building with a Phase Two score less than 1.0 fails the LANL Seismic Screening Method. The inspector's work is complete.

The above screening scores are considered preliminary until a tiered review process has been completed. Reference the Quality Assurance and Review Requirements section of this handbook for details.

It should be noted that a detailed seismic analysis is not a part of the LANL Seismic Screening Method. However, such an analysis may reveal that the building has adequate life-safety characteristics even after failing the LANL Seismic Screening Method. This is because of the conservatisms inherent in the LANL Seismic Screening Method.

Screening Summary Report

All information on the field data form will be entered into the LANL seismic database. The field data forms are worksheets for the inspector's use in the field.

The final, official record of data for each building will consist of a Completed Screening Data Report. This report will summarize the screening results from the seismic database. An example of a Completed Screening Data Report is included in the Appendix.

Nonstructural Hazards

Nonstructural elements may also pose a life-safety hazard. Although FEMA 154 does not provide performance modification factors for nonstructural hazards, it is important to catalogue potential life-safety hazards resulting from displacement of construction materials, building equipment, furnishings, and hazardous contents. Particular attention must be given to means of egress such as corridors, stairways, lobbies and exit pathways. Failure of nonstructural elements in these areas could delay or prevent building evacuation.

The second page of the field data form lists several potential deficiencies related to nonstructural elements. Although not a factor in the screening scores, all deficiencies will be entered into the seismic database. The most serious deficiencies will be evaluated and recommended for correction.

Following is a summary of possible nonstructural hazards to look for and circle on the field data form. These hazards have been adopted from FEMA 178.[n]

Ceilings

- Inadequate or nonexistent lateral bracing of suspended ceiling systems.
- Ceilings constructed of suspended plaster or gypsum board.
- Lay-in tiles used as ceiling panels.
- Edges of ceiling attached to structural walls or columns.
- Ceiling system continuous across expansion joints.
- Ceiling system providing the only lateral bracing for partitions.

Light Fixtures

- Light fixtures relying solely on ceiling system for support and bracing.
- Multiple-length fluorescent fixtures not braced.
- Diffusers on fluorescent fixtures not positively attached to the fixture frames.
- Pendant-style light fixtures used.
- Double-stem fluorescent fixtures used.
- Emergency lighting equipment and signs not adequately anchored or braced.

Cladding and Glazing

- Exterior cladding or veneer not adequately anchored to the back-up structural systems to resist out-of-plane and in-plane lateral forces.

- In **Type 3** *Steel Moment Frame*or **Type 8** *Concrete Moment Frame* buildings, cladding panels not isolated from the structural frame (also multifloor panels in other building types having anchorage not designed for interstory drift).
- Less than two bearing connections per panel.
- Where used, concrete inserts not anchored to reinforcing steel.
- Less than four anchors per panel capable of resisting out-of-plane loads.
- Welded connections not designed to preclude brittle failure.
- Cladding connections or anchors damaged, deteriorated or corroded.
- Cracks in panels that might indicate structural distress.
- Damage to cladding resulting from water infiltration.
- Damage to cladding resulting from temperature movements.

PARTITIONS

- Unreinforced masonry partitions used.
- Partitions not detailed to accommodate interstory drift.
- Partitions continuous across expansion joints.
- Tops of partitions not braced.

VENEER

- Lack of metal ties between veneer and the back-up support system.
- Mortar joints with missing, deteriorated, or soft mortar.
- Masonry veneer located more than 30 feet above ground not supported by lintels or shelf angles at each floor level.
- Substantial corrosion of metal ties between the veneer and the back-up support system.

PARAPETS, CORNICES, AND ORNAMENTATION

- Laterally unsupported, unreinforced masonry parapet having a height/thickness ratio greater than 2.5.
- Laterally unsupported concrete parapet without vertical reinforcing steel and having a height/thickness ratio greater than 2.5.
- Cornices, parapets, signs, etc. that extend from the building not adequately anchored or braced.

MEANS OF EGRESS

- Unreinforced masonry used adjacent to corridors, stairways, room exits, building exits.

- Non-life-safety piping or equipment located in stairways.
- Lay-in tiles used as ceiling panels.
- Ceiling-mounted light fixtures not positively attached or braced.
- Inadequate anchorage or bracing of veneers, cornices, canopies, or other ornamentation above building exits.

Furnishings

- Unanchored file cabinets, storage racks, bookcases, etc. with height/depth > 3.
- Cabinet drawers without latches.
- Breakable items on shelves not restrained from falling by latched doors, shelf lips, or other methods.
- Tall computer modules or other communications equipment not anchored to the floor or walls.

Equipment and Piping

- Free-standing electrical or mechanical equipment not adequately anchored to the floor; also, vibration isolators not equipped with lateral restraints.
- Suspended electrical or mechanical equipment not adequately anchored or braced.
- Sprinkler system, gas piping, or other process piping not adequately anchored or braced.
- Piping not equipped with flexible couplings at building expansion joints.
- Pipes supported by other pipes.
- No shut-off devices provided where utilities enter building.

Ducts

- Long lines of ducts not adequately braced to prevent sway (for ducts greater than 6 square feet in area or 28 inches in diameter).
- Ducts supported by piping or other ducts.
- Lack of flexible sections where ducts cross building expansion joints.

Hazardous Materials

- Unrestrained compressed gas cylinders.
- Hazardous materials stored in breakable containers that are not restrained from falling.
- Hazardous material process piping not provided with shut-off devices to prevent major spills or leaks.

Quality Assurance and Review Requirements

To insure the quality of the screening results for uniformity of application and technical accuracy, a tiered, dual-level review will be performed.

- All screened buildings will receive an internal review.
- All PC-3 buildings, as well as all **Type 7** *Steel Frame with Infill Shear Walls*, **Type 10** *Concrete Frame with Infill Shear Walls*, and **Type 15** *Unreinforced Masonry Bearing Wall Buildings* automatically fail the screen and will receive an internal review only.
- Buildings that have undergone or are currently undergoing detailed seismic analyses or retrofit automatically fail the screen and will receive an internal review only.
- All designated essential buildings will receive both an internal review and an external peer review.

Both tiers of the review process are described below:

Internal Quality Assurance and Review

The screening results for all buildings and sectors will be reviewed by an in-house structural engineer. The internal review will consist of verifying proper application of Phase One building types and modifiers and accuracy of the Phase Two capacity/demand calculations. The internal reviewer will also verify that all information has been correctly transferred from the field data form to the seismic database.

The internal reviewer will indicate that these steps have been completed by filling out the "Reviewer" and "Date" spaces on the field data form.

"Marginal" buildings and sectors will be subject to an independent external peer review. "Marginal" buildings and sectors are defined as those having a Phase One score between 1.5 and 2.5 or a Phase Two score between 0.80 and 1.20.

External Peer Review

All "marginal" buildings and sectors will be reviewed by an independent structural engineer who has significant expertise in evaluating seismic behavior of buildings to verify the accuracy of the screening. The external peer review will consist of verifying proper application of Phase One building types and modifiers and accuracy of the Phase Two capacity/demand calculations and analysis assumptions. Detailed structural analysis methods should not be employed. However, particular emphasis on load path and connection detailing is required.

The external peer reviewer will note any discrepancies and the effect these would have on the scores. Also, the external peer reviewer will work with the internal reviewer to resolve any differences. Once all differences are resolved and necessary data corrections have been entered into the seismic database, the screening is complete.

References

a. "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components," DOE Standard STD-1021-93 (United States Department of Energy, Washington, D.C., July 1993).

b. "Seismic Safety of Existing Federally Owned or Leased Buildings," Executive Order 12941, 59 F.R. 232.

c. G. O. Fritz, "Metodo Aproximado para la Determinación de Zonas Límite para el Periodo de Vibración en Estructuras Cimentadas en Diversos Tipos de Terreno en el Distrito Federal," Departamento del Distrito Federal, Secretária General de Obras, México (1986).

d. J. Iglesias Jimenez, et al., "Intensidad del Sismo de 1985 en la Ciudad de México," Simposio Nacional de Ingenieria Sismica, Ixtapa, Zihuatanejo, México, Noviembre de 1986.

e. "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook," FEMA 154 (Federal Emergency Management Agency, Washington, D.C., July 1988).

f. "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA 222 (Federal Emergency Management Agency, Washington, D.C., 1991).

g. "Uniform Building Code," UBC-94 (International Conference of Building Officials, Whittier, California, 1994).

h. "Final Report: LANL FY95 Seismic Screening Assessment Results," Volume I, Johnson Controls World Services, Inc., report (September 1995).

i. "Peer Review: LANL Seismic Screening Assessment Method," Degenkolb Engineers, report (October 2, 1995).

j. "Response to Dekenkolb Engineers Peer Review of the LANL Seismic Screening Assessment Method," Paragon Structural Engineering, LLP, report (January 5, 1996).

k. "Peer Review: LANL Seismic Screening Assessment Method," Degenkolb Engineers, report (March 25, 1996).

l. "Peer Review: LANL Seismic Screening Assessment Method," Degenkolb Engineers, report (May 14, 1996).

m. D. E. Volkman, "Clarifications on Degenkolb's May, 1996, Peer Review LANL Seismic Screening Methodology," Los Alamos National Laboratory memorandum to Paragon Structural Engineering and Degenkolb Engineers (May 15, 1996).

n. "NEHRP Handbook for the Seismic Evaluation of Existing Buildings," FEMA 178 (Federal Emergency Management Agency, Washington, D.C., June 1992).

o. J. Iglesias Jimenez, "Evaluación de Edifícios de Concreto en la Cuidad de México," Revista Construcción y Tecnologia, México (Agosto de 1989).

p. R. Meli, et al., "Guerrero Earthquake in September 1995," Seismological Letters, Seismological Society of America (December 1995).

q. J. E. Bowles, *Foundation Analysis and Design*, 4th ed. (McGraw-Hill, Inc., New York, 1988), Chapter 11, pp. 517-518.

r. "Building Code Requirements for Masonry Structures,"ACI 530-88 (American Concrete Institute, Detroit, Michigan, 1989).

s. "Specification for Structural Steel Buildings: Allowable Stress Design and Plastic Design, Ninth Edition" (American Institute of Steel Construction, Inc., Chicago, Illinois, 1989).

t. B. Stafford Smith and A. Coull, *Tall Building Structures: Analysis and Design* (John Wiley and Sons, Inc., New York, 1991), Chapter 8, pp. 168-172.

u. "Standard Method for Penetration Resistance," ASTM D1586 (American Society for Testing and Materials, Philadelphia, Pennsylvania).

v. "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," DOE Standard STD-1020-94 (United States Department of Energy, Washington, D.C., April 1994).

w. "A Seismic Hazards Evaluation of the Los Alamos National Laboratory," Woodward Clyde Federal Services, Oakland, California, report (February 1995).

APPENDIX

FIELD DATA FORM—GENERAL BUILDING AND STRUCTURAL CONFIGURATION CHECKLIST

FIELD DATA FORM—NONSTRUCTURAL HAZARDS CHECKLIST AND COMMENTS

STRUCTURAL SCORES AND MODIFIERS

EXAMPLE COMPLETED SCREENING DATA REPORT

LANL Seismic Screening - Field Data

General Building and Structural Configuration Checklist

Inspector: ______________________ **Date:** ____________

Reviewer: **Date:**

TA: **Sector:** **Bldg. Mgr.:** **Phone:**

Bldg: **Sector Description:**

Structure Description: ______________________

Wood		Steel				Concrete		Infill Walls		Precast		Masonry		
Light	Comm/Ind	MRF	BR	LM	RCSW	MRF	SW	Steel	Conc	Flex Dia	Rigid Dia	RM/Flex	RM/Rigid	URM
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Population: *0-5* *6-50* *51-300* *300+* *Actual from Database:* ________

Occupancy: Office, Lab, Shop, Storage, Utility, ________

Design Date: ________ **Post-Benchmark:** Yes / No [ ]

Benchmark Year: ________

Drawing Numbers: ________

Size — Length ___ ft; Width ___ ft; Area ___ sq ft; Height ___ ft; Stories

High Rise [ ] — H >= 8 Stories; H >= 100 ft; H/L >= 5

Incomplete Load Path [ ] — Incomplete; Complete. Description: ________

Poor Condition [ ] — Diagonal Shear Cracks; Extensive Corrosion; Rot or Pest Damage; Inferior Mortar Joints; Lack of Adequate Bearing; Vertical Foundation Movement; Column Tilting

Vertical Irregularity [ ] — Vertical Irregularity > 130%; In-Plane Offset; Weak Story < 80%; Weight Irregularity > 150%; Sloped Walls or Columns; Sloped Grade > 1 Story

Plan Irregularity [ ] — Reentrant Corners > 15%; Attached Sector Area > 20%; Aspect Ratio > 2:1; Large Tilt-up Building > 100,000 sf; Diaphragm Discontinuity > 50%; Out-of-Plane Offset; Nonparallel System

Soft Story [ ] — Long Columns > 113%; Missing Columns

Torsion [ ] — Eccentricity > 20% by Inspection; Eccentricity > 20% by Calculation

Large Heavy Cladding [ ] — >15 psf Panels on Frame Type Building

Short Column [ ] — Partial Height Infill Walls; Intermediate Beams

Soil Type — Soft; Medium; Rigid

Pounding [ ] — d ___ ft; H ___ ft; d/H

Scores: **Base Score:** [ ] **Phase One:** [ ] **Phase Two:** [ ]

Comments: ______________________

FIELD DATA FORM—GENERAL BUILDING AND STRUCTURAL CONFIGURATION CHECKLIST

LANL Seismic Screening - Field Data			
Non-Structural Hazards Checklist			
Inspector: ______________		*Date:* ________	
Reviewer:		*Date:*	
TA:	*Bldg:*	*Sector:*	
Ceilings	Inadequate Bracing Suspended Plaster or Gyp Board Lay-in Tiles Attached to Structural Systems No Separations at Exp. Joints Ceilings Support Partitions	***Light Fixtures***	Supported Only by Ceiling Unbraced Multi-Length Fixtures No Latches on Diffusers Pendant Fixtures Double-Stem Fluorescents Poor Emergency Light Anchorage
Cladding and Glazing	Poor Anchorage Potential Damage Due to Drift <2 Bearing Connections per Panel Concrete Inserts Not Reinforced <4 Lateral Load Anchors per Panel		Non-Ductile Welded Connections Connection Damage/Deterioration Cracks in Cladding Panels Damage from Water Infiltration Damage from Thermal Movement
Partitions	URM Partitions Used Potential Damage Due to Drift No Separations at Exp. Joints Unbraced at Top	***Veneer***	Lack of Veneer Ties Inferior Mortar Joints No Lintels for Veneer >30' High Deteriorated Ties or Anchors
Parapets, Etc.	URM Parapet Height > 2.5t No Vert. Rebar (Conc. Parapets) Inadequate Anchorage of Projecting Ornamentation	***Means of Egress***	URM Used at Stairways, Corridors Excessive Piping in Stairways Mech. Equipment in Stairways Unsecured Ceiling Tiles, Fixtures Unanchored Canopies over Exits
Furnishings	Unanchored Cabinets, Racks or Shelves with Height Ration >3:1 No Latches on Drawers or Doors Unrestrained Breakable Items Unanchored Computers, etc.	***Equipment & Piping***	Unanchored Equipment Unbraced Suspended Equipment Unbraced Suspended Piping No Flex Couplings at Exp. Joints Pipes Supported by Other Pipes No Shut-off Devices at Building
Ducts	Unbraced Suspended Ducts Ducts Supported by Pipes, etc. No Flex Couplings at Exp. Joings	***Hazardous Materials***	Unrestrained Gas Cylinders Unrestrained Breakable Items No Shut-off Devices
Comments: ______________			

FIELD DATA FORM—NONSTRUCTURAL HAZARDS CHECKLIST AND COMMENTS

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	1 W/Light	2 W/Comm	3 Stl MRF	4 Stl BR	5 LM	6 RCSW	8 Conc MRF	9 Conc SW	7/10 Infill	11 TU/Flex	12 TU/Rigid	13 RM/Flex	14 RM/Rigid	15 URM
DESCRIPTION	Wood or Steel Stud	Wood Post-and-Beam	Steel Moment Frame	Steel Braced Frame	Pre-Engineered Steel Building	Steel Frame w/ Concrete Shear Walls	Concrete Moment Frame	Concrete Shear Wall	Steel or Concrete Frame w/ Infill Shear Walls	Precast/Tilt-Up Concrete Walls w/ Flexible Diaphragm	Precast Concrete Frames w/ Concrete Shear Walls	Reinforced Masonry Walls w/ Flexible Diaphragms	Reinforced Masonry Walls w/ Precast Concrete Diaphragms	Unreinforced Masonry Shear Walls
Basic Score	6.0	6.0	4.0	3.0	6.0	4.0	3.0	3.5	2.0	3.5	2.0	3.5	3.5	2.0
Incomplete Load Path*	-4.5	-4.5	-2.5	-2.5	-4.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
High Rise	N/A	N/A	-1.0	-0.5	N/A	-1.0	-0.5	-1.0	-1.0	N/A	0.0	-0.5	-0.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-0.5	-1.0
Soft Story	-1.0	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0	-1.0
Pounding **	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Heavy Cladding	N/A	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	N/A	-1.0	N/A	-1.0	N/A	-1.0	N/A	N/A	N/A
Post Benchmark ***	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	N/A	+2.0	+2.0	N/A
UBC Edition	1949	1949	1976	1988	1988	1976	1976	1976		1973		1976	1976	

* Incomplete Load Path Modifier shall be reduced by 50% if minimal load path is present

** Pounding Modifier only applicable if one or more adjacent buildings or sectors is Building Type 3, 4, 5, 6, 8, or 12.

*** Post Benchmark Modifier not applicable if Incomplete Load Path Modifier is present.

TA: **02** Building: **0001** Sector: **B**

Completed Screening Data

19-Jun-96

Building Title: **CANYON SCHOOL**

Sector Title: **Omega Annex**

Inspector: **Dickson**

Inspection Date: **7/6/95**

Building Data:

Size:	Length	Width	Gross Bldg Area	Sector Footprint	Height	Stories Above Grade
	50.63 ft	30.50 ft	33,596 SF	1,544 SF	19.75 ft	1

Structure Type: **1: Wood, Light Frame**

Description: **Wood-framed addition attached to NE corner of Sector A. Roof is timber trusses & some 2x12 rafters. Walls are 2x6 stud infill between 6x6 posts anchored to RC stem wall. Stem wall heights vary from 2'-6" to 9'-0". Floor is slab-on-grade w/ perimeter strip footings.**

Soil Type: **Medium**

Occupancy: **Lab**

Bldg. Population: **93**

Building Manager: **Mike Demaria**

Design Date: **9/23/44**

Phone: **5-2233**

Dwg Numbers: **C1687**

Scoring Data:

Base Score:	Structure Type:	**1: Wood, Light Frame**	**6.0**
Modifiers:	Incomplete Load Path:		
	High Rise:		
	Poor Condition:		
	Vert. Irregularity:		
	Plan Irregularity:	**Attached Sector > 20%**	**-1.0**
	Soft Story:		
	Torsion:		
	Heavy Cladding:		
	Short Column:		
	Pounding, d/H:		
	Benchmark Year:	**1949**	
Phase One Score:			**5.0**
Phase Two Score:			**0.7**

Comments: **Shear Score for Sectors B & E combined.**

SAMPLE COMPLETED SCREENING DATA REPORT