Portland State University
Services and Parking No. 2 Building

FEMA-178 Seismic Evaluation

Prepared For:
Portland State University
Portland, Oregon

Prepared By:
VLMK Consulting Engineers
3933 SW Kelly Avenue
Portland, Oregon 97201

March, 1999
March 19, 1999

Mr. Burt Ewart
Portland State University
Post Office Box 751
Portland, Oregon 97207-0751

Re: FEMA-178 Seismic Evaluation
Services and Parking No. 2 Building
617 SW Montgomery
Portland, Oregon

Dear Mr. Ewart:

In accordance with our proposal, VLMK Consulting Engineers has completed a Seismic Evaluation of the Services and Parking No. 2 Building located on the campus of Portland State University in Portland, Oregon.

Following the FEMA-178 guidelines, several deficiencies were identified. These include problems with adequate overturning resistance in a number of the garage shear walls and offset levels between the garage and office portions of the building, which is only further hampered by the building’s ‘L’ shape. A number of nonstructural deficiencies were also noted and largely relate to a need for proper bracing of various building components and contents.

In our opinion, the office portion of the building represents a low seismic risk and the garage a moderate seismic risk. As such, in a seismic event some damage can be expected, including the possibility of localized failure at the garage/office interface.

We appreciate the opportunity to be of service and look forward to working further with you on this and other projects in the future. If you have any questions or concerns regarding this report or would like additional information, please do not hesitate to contact us at your convenience.

Sincerely,

VLMK Consulting Engineers

Trent C. Nagele
Structural Designer

James E. Knauf, P.E.
Principal
Portland State University
Services and Parking No. 2 Building
FEMA-178 Seismic Evaluation

EXECUTIVE SUMMARY

At the request of Portland State University, VLMK Consulting Engineers completed an investigation of the Services/Parking 2 Building located on the PSU campus in Portland, Oregon. The report follows the format and guidelines outlined in the National Earthquake Hazards Reduction Program (NEHRP) Handbook for the Seismic Evaluation of Existing Buildings – Federal Emergency Management Agency (FEMA) 178/June 1992. Information about the building was obtained from a review of original construction documents, visits to the site, recent soil and seismic hazard information, and engineering analysis.

The PSU Services/Parking 2 building is believed to have been constructed in 1969 based on the date of the original drawings. In total, it encompasses nearly 168,000 square feet, with about two-thirds of that utilized for parking. The remainder is utilized for various campus services and a small retail space. Construction of the building's structural system is entirely concrete. The roof and intermediate levels are concrete waffle slabs that are supported by concrete columns and walls. A concrete slab on grade is used in the basement and covers shallow concrete spread footings that form the foundation.

The “shaking” ground motions caused by an earthquake are treated analytically as horizontal forces acting on a building or building component. These forces are resisted in a building of this type by the roof, floors and walls (also known as shear walls). For this system to work, adequate strength of, and connections between, the respective members must be present. In this building there is adequate shear strength. However, a number of the garage walls do not have sufficient capacity to resist overturning with the increased seismic loads now considered by current codes and practice. Correcting the overturning problems would likely require a combination of strengthening the walls and adding additional lateral elements to reduce the overturning forces seen by a single element.

Another significant deficiency is the lack of continuity between diaphragms (or levels) through the interface between the garage and office portions of the building. This problem, coupled with an irregular ‘L’ shape may produce a tearing and pounding effect between the two portions of the structure, resulting in sizeable damage and the potential for localized collapse. Addressing the diaphragm discontinuities might be done by either providing separation between the two building portions, or by increasing the capacity of the common elements, namely the shared wall, and adding drag struts to better tie the structure together.

A number of nonstructural elements were identified in the building. These items, though not typically a direct threat to life safety, can cause harm to occupants during an earthquake or potentially block exits. The interior gypsum partition walls are attached to the ceiling grid.
without any independent bracing. Similarly, the suspended ceiling is not braced for lateral load and the light and mechanical fixtures do not have independent support or bracing. The danger with these elements is that excessive deflections in the ceiling system can cause tiles and/or fixtures to fall. A general lack of proper bracing or anchorage is also present with much of the mechanical and electrical equipment and piping. Correcting these deficiencies is largely a matter of providing the proper bracing or anchorage in accordance with current codes and practices.

Quantifying a precise level of risk and damage for a building following a significant earthquake is not easily accomplished, and is beyond the scope and intentions of this type of seismic evaluation. In general, however, it is our opinion that the anticipated risk and expected damage would place the office in a low category and the garage in a moderate category of risk, when compared to other structures of similar size and construction in this area.
Portland State University
Services and Parking No. 2 Building
FEMA-178 Seismic Evaluation

At the request of the Portland State University (PSU) Facilities Department, the following Seismic Evaluation has been completed for the Services/Parking 2 Building located on the PSU campus at 617 SW Montgomery in Portland, Oregon. The evaluation follows the guidelines in the National Earthquake Hazards Reduction Program (NEHRP) Handbook for the Seismic Evaluation of Existing Buildings - Federal Emergency Management Agency (FEMA) 178 / June 1992.

REPORT SCOPE AND LIMITATIONS

The primary purpose of an evaluation conducted under the NEHRP Handbook, also commonly referred to as FEMA-178, is to identify life safety hazards posed by the building or a particular building component. As described in the FEMA-178 document, "A building does not meet the life-safety objective of this handbook if, in an earthquake, the entire building collapses, portions of the building collapse, components of the building fail and fall, or exit and entry routes are blocked preventing the evacuation and rescue of the occupants." Consequently, this report’s scope is largely limited to identifying those items that relate to life safety. Strictly speaking, it does not address issues such as code compliance and damage control, nor does compliance with the report evaluation ensure that the building will be serviceable following an earthquake. Nevertheless, some comments relating to these issues are provided in order to provide a better understanding of the building’s condition and to assist in planning for future upgrades. In addition, the report also contains a review of many of the nonstructural elements (those components which are not part of the primary structural supports or lateral force resisting system), which can pose a hazard to people in and around the building during an earthquake. Examples of nonstructural elements include building contents, partition walls and exterior veneers.

Preparation of this Seismic Evaluation was based on information obtained from the following sources:

1. A review of the original architectural and structural drawings dated May 1969.
2. Review of portions of the original building specifications dated May 1969.
3. Several visits to the site, including a complete walkthrough of the building.
4. Soil reports from this and adjacent structures:
   a. Services/Parking 2 Building - Dames & Moore, November 1967
   b. Professional School Building – Foundation Investigation, Dames & Moore, February 1978
5. Previous work with this building, and experience with other buildings of similar size and construction.

BUILDING TYPE, CONSTRUCTION AND HISTORY

The Services/Parking 2 Building is a single concrete building that incorporates a parking garage with office, shop and storage spaces. Total area of the building is approximately 168,000 square feet. About two-thirds of the building is a parking garage, while the remaining one-third is office, workshop and storage space that is utilized for various campus services. A recent remodel in the northwest corner converted approximately 4,500 square feet of garage space into retail. The parking portion of the building has a basement plus 5 levels (including the roof) that continuously slope to allow movement of traffic from one level to another. In the office area, there is a basement and 4 upper levels, though the floor elevations do not always match those of the adjacent garage.

The original drawings are dated May 1969, and were prepared by Witt, Englund, Plummer A.I.A. Architects. Cooper & Rose & Associates did the structural engineering work on the project. Both firms were located in Portland. Structural design was performed in accordance with the 1967 Uniform Building Code, which at the time placed Portland in Seismic Zone 2.

Construction of the building's primary structure is entirely cast-in-place concrete. Masonry partitions, in-fills and veneers have been used in various portions of the building, but are considered nonstructural. A summary of the major structural elements is as follows.

**Table 1 - Typical Building Construction**

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>Concrete waffle slab. Typically a 3&quot; slab with 14&quot; joists (17&quot; total depth) utilizing a 30&quot;x30&quot; pan. Conventional reinforcement varies in joists, though slab has #3 bars each way at 9&quot; o.c. between joists.</td>
</tr>
<tr>
<td>Intermediate Levels</td>
<td>Same as roof</td>
</tr>
<tr>
<td>Basement</td>
<td>4&quot; Concrete slab on grade reinforced with 6x6-10/10 welded wire mesh.</td>
</tr>
<tr>
<td>Vertical Load Bearing System</td>
<td>Office: Exterior concrete walls with interior concrete columns. Walls are 10&quot; thick at lower levels and 8&quot; at upper levels. Columns are 22&quot;x22&quot; (24&quot;x24&quot; in basement). Garage: Exterior concrete walls with a central interior wall and interior concrete columns. Walls are typically 10&quot; and 8&quot; thick. Columns are square and rectangular with varying dimensions.</td>
</tr>
<tr>
<td>Foundation</td>
<td>Concrete spread footings</td>
</tr>
<tr>
<td>Lateral System</td>
<td>Concrete shear walls located primarily at the exterior, but with interior walls in the garage and at stairs and elevators.</td>
</tr>
</tbody>
</table>

Based on the building construction and lateral resisting system, it would be classified as a Type 9: Concrete Shear Wall building according to FEMA-178.
Located directly adjacent to the southwest portion of the parking garage is the Campus Ministries Center. This building predates the Services/Parking 2 Building. A 2" seismic joint separates the two structures.

SEISMIC LOAD PATH

The seismic load path in any building is simply the means by which loads, acting laterally on the building, may be transferred from the roof and each level down to the foundation. The following paragraphs explain this concept in a generic sense and then specifically discuss the load path present in the Services/Parking 2 Building.

General Explanation

Loads such as wind and earthquake are typically considered to act on a building in a lateral (horizontal) direction, hence the term lateral load. To understand how loads are transferred in a simplified case, consider the one story illustration shown below. A lateral load is applied perpendicular to a wall as shown. The wall then spans, much like a beam, between the foundation and roof (or floor in a multistory building). As a result, a portion of the lateral load will be transferred into the roof. The roof (called a diaphragm), in turn, spans between the walls (called shear walls) on either side of the building and transfers load to them in the form of shear. Finally, the shear wall transfers this shear load to the foundation, and then the ground, completing the lateral load path.

Although these load paths become more complex in larger buildings, the basic underlying concepts still apply. A complete load path must be defined for any building. If a portion of this path is missing, the building has the potential to collapse. For instance, in the illustration, if the shear walls were removed, it is clear that the structure would be unstable and easily collapse. (Try removing two sides of a cardboard box and then pushing on it.) The same type of argument might also be made if the connection between the diaphragm and roof was missing or lacked adequate strength. Again, various degrees of instability would be introduced. In many buildings, elements other than shear walls are used to transfer lateral loads and provide stability; these include rigid (moment) frames and braced frames.
Specific Description
The lateral resisting elements utilized in the Services/Parking 2 Building are shear walls. They are oriented in both of the major building axis directions (e.g. north/south and east/west). Each of the rigid diaphragms at the roof and floors is continuously connected to the shear walls as a single reinforced concrete unit. Typically, the waffle joist reinforcement (top and bottom) terminates in the wall with a standard hook that is bent over the typical horizontal wall reinforcement. Loads from the shear walls are transferred to the foundation and then the ground. Vertical dowels between the foundation and walls are placed to match the size and spacing of the wall reinforcing, and typically lap 2'-0".

Calculation of seismic forces is a function of the building weight. In the intervening years since this building's construction, the opinion of seismicity in the northwest has changed significantly. Correspondingly, the code prescribed seismic forces have increased to reflect this new philosophy of the regions fault structure and the heightened level of risk it represents. The following graph illustrates the changes in required seismic forces, as they relate to this structure, expressed as a percentage of building weight. The change, for instance, between the 1967 (6%) and 1997 (20%) Uniform Building Code (UBC) force levels represents an increase of well over 300% as shown below.

![Seismic Force as % of Building Weight](image)

QUICK CHECK
From previous work with this building, it was already known that many shear walls would not meet the conservative shear limitations encompassed in the FEMA-178's Quick Check method. Namely, a limitation of 55 psi (based on 3,000 psi concrete) shearing stress in shear walls. Therefore, a more detailed evaluation of the structure was performed following the procedures outlined in the FEMA handbook.

Standard linear static analysis methods were used to evaluate the building. With this method, lateral forces were distributed horizontally to the various shear elements based upon their relative rigidities. Similarly, overturning moments resulting from shear in the primary direction were also distributed to elements based upon their contribution to the overall system at a given level. To address the discontinuities presented by the offset diaphragms, the garage and office were analyzed separately, except at the 4th-office/5th-garage level where the two diaphragms have the same elevation.
It is recognized that in many respects the building is classified as an “irregular” structure. As such, the currently accepted method of analysis would be based on a linear dynamic model. However, for the purposes of this report a static model was considered adequate for gaining an initial, quantifiable understanding of the building’s present condition. Indeed, it is almost certain that the original design work was based on static methods. Nevertheless, any large-scale modifications or upgrades to the building should incorporate a dynamic analysis of the structure to more precisely quantify the effects of the buildings “irregularities”.

EVALUATION STATEMENTS

In preparing a Seismic Evaluation following the FEMA-178 guidelines, a series of true or false statements are evaluated for a given building. A "True" response to a statement indicates that a given item satisfies the FEMA-178 guidelines. "False" responses indicate an area that does not meet the guidelines. These items should be corrected or further evaluated. The statements discussed below were either found to be "False", could not be answered definitively within the scope of this report, or merited further comment. A complete listing of the evaluation statements is given in Section 5. It is suggested that they be reviewed to not only gain a more complete understanding of the strengths and weaknesses of the structure, but to also better understand some of the specific concerns which should be considered in the future, particularly with regard to nonstructural items.

Building Systems

- **Vertical Irregularities**: The majority of shear walls are continuous to the foundation. However, the main level of the garage has a large concrete wall oriented in the north/south direction adjacent to the ramp leading to the basement. This wall occurs only at this level and does not extend to the basement. Nevertheless, its presence does attract a significant amount of shear that then has to be redistributed at the 1st level diaphragm. The diaphragm is adequate to transfer calculated shears, but there are some significant vertical loads from overturning introduced.

- **Torsion**: Although calculations show that offsets between the center of rigidity and center of mass do not exceed 20% of the width of the structure, the degree of offset, coupled with an irregular ‘L’ shape, does present some concerns. Future plans for the building may want to include means for reducing the torsional contributions to shear. See related discussion on diaphragm discontinuity below.

Shear Walls

- **Shearing Stress Check**: The building does not satisfy the Quick Check of shearing stress in shear walls, which limits these stresses to approximately 55 psi for the initial evaluations. However, as explained previously in the Quick Check section, more precise
calculations done in accordance with the ACI provisions shows that these walls have sufficient shear strength to resist the loads prescribed in the FEMA Handbook.

- **Overturning:** Although the majority of the shear walls have a height/length ratio which is less than 4:1, calculations show that a number of these walls, particularly in the garage, are not sufficient to resist the overturning forces. In many of these locations, the deficiency is in the tensile capacity of the wall. A lack of boundary elements to confine high compressive stresses is also a problem in several areas as discussed below. Note that the deficiency in overturning resistance is largely the result of an increase in seismic forces from those prescribed in the 1967 Uniform Building Code.

- **Confinement Reinforcing:** None of the shear walls are detailed with specific boundary elements to confine extreme ends of the wall and provide ductility in areas of high compressive stresses. This deficiency, however, is primarily a problem only in portions of the garage where the compressive stresses are high enough to require boundary elements.

### Diaphragms

- **Plan Irregularities:** The building configuration is an ‘L’ shape. Consequently, there is a significant re-entrant corner at the bend in the ‘L’. In a seismic event, there is a tendency for the building to tear at this corner. Typically, this force is resisted by strengthening the diaphragm. However, because of the sloping offset levels in the garage, the diaphragms do not align at this juncture. The result is that any “tearing” force at this location will produce bending in the common wall between the office and garage areas. Aside from the typical wall reinforcing, no additional reinforcing is provided to strengthen this wall. As a result, there is potential for portions of this wall to fail in a significant seismic event due to buckling induced by lateral forces applied by the diaphragms at intermediate heights of the wall.

### Capacity of Foundations

- **Sloping Sites:** The grade difference between extreme corners of the building (diagonally) is about 10'-0". However, given the degree of slope and site conditions, slope stability is not considered a problem. Further, sloping levels within the building follow this grade change to a large degree, thereby mitigating much of the potential for other problems associated with grade changes.

### Nonstructural Elements

An overview of the nonstructural elements was performed and areas of deficiency or concern are noted below. The evaluation statements (See Section 5) provide additional information on the types of items that are of concern and should be avoided.
• **Partitions**
  a. The 4th level of the parking garage contains a CMU enclosure for electrical equipment. The walls stop approximately 3” short of the structural slab above and no attachment or bracing is present. Further, no grouting in the wall could be identified. The woodshop contains a partial height CMU wall, which, though not braced, has solid grouting and pilasters. These elements should provide sufficient strength for the wall to span horizontally between building columns and pilasters, assuming proper reinforcing is present.
  b. Interior metal stud and gypsum board partition walls only extend to the height of the suspended ceiling and are not laterally braced to the structure. This condition is typical throughout nearly all of the office areas.
  c. The fixed glass is not necessarily detailed to accommodate interstory drift. However, the office area, which encompasses nearly all of the glass, is relatively stiff and is not anticipated to experience problems with excessive interstory drift.

• **Ceiling Systems**
  a. The suspended T-bar ceiling system has no lateral bracing. Similarly, the lighting and mechanical fixtures supported by the ceiling are not laterally braced.
  b. Lay-in tiles are not secured. Although not usually a concern in itself, the lack of lateral bracing for the ceiling system can result in excessive deflections that in turn can cause ceiling tiles to fall. Lay-in tiles should be secured with clips, particularly in areas of egress.
  c. The edges of the ceiling are fastened to structural walls.
  d. Gypsum board partition walls are attached to the ceiling system as their only means of lateral bracing.

• **Light Fixtures**
  a. Light fixtures in the suspended ceilings are not supported independently of the ceiling system. Although support for the T-bar ceiling system is often located adjacent to light fixtures, excessive deflections in the ceiling may cause them to fall.
  b. In a number of locations, and particularly in the shop and storage areas, multiple length fluorescent fixtures are suspended with a stem or chain, but have no additional means of bracing. Concern with these elements is that fixtures can severely swing and/or twist, resulting in breakage of stems, chains or their respective structural attachments. Also, fixtures can bang against each other or into other building components, causing elements to break and fall.
  c. In the office areas, diffusers on the fluorescent lights are similar to the lay-in ceiling tiles and are not considered a very likely falling hazard. However, many of the fluorescent fixtures in the shop and storage areas do not have diffusers. Consequently, while there is no danger of the diffuser falling, there is also no means to contain elements that may separate from the housing and fall.
  d. Many pendant fixtures are present. Please see above for discussion of the multiple length fluorescent fixtures. In addition, lighting in the garage is provided by short, single lamp, pendant fixtures. These lights are suspended from the electrical box and
appear quite flimsy. Potential for damage to the connection or outer fixture resulting from earthquake motion seems good.

e. In some locations, emergency lighting equipment and signage is attached to the suspended ceiling without independent support or bracing.

• Cladding, Glazing and Veneer

a. Brick tile veneer is attached to the exterior of the building (office portions) and has concrete backup. Original specifications for the building indicate that it was placed following construction of the wall (as opposed to being cast with the wall). No mechanical fasteners were used; rather it is adhesion between the mortar and concrete that provides anchorage. Although not in specific compliance with the FEMA guidelines, it is our opinion that the anchorage of these brick tiles does not represent a significant concern.

b. Anchorage of the precast concrete fins in the garage area is provided by bolted clip angles at the base with a 3/4” thru-bolt. The top of the fins is fitted with a 1” diameter steel pin set loose in a 1 1/4” pipe socket. The adequacy of reinforcement around either of these connections is unknown. The overall condition of the panels is good and no significant deterioration of the concrete was noted. It is recommended that additional investigations (destructive or nondestructive) be made in conjunction with future upgrade plans.

• Chimneys

The immediately adjacent Campus Ministries building has a concrete block chimney which extends above the highest level of the parking structure by more than twice the least dimension of the chimney. Reinforcement and anchorage of the chimney is unknown. A two-inch seismic gap separates the structures. Considering that the Campus Ministries building was constructed prior to 1969, the likelihood of proper reinforcement, coupled with a potential for pounding, raises concerns regarding the adequacy of the chimney to withstand a significant seismic event.

• Means of Egress

a. The main corridor of the services building contains concrete block partition walls that are, for the most part, unreinforced. Bracing is provided at the top of the wall by angles which are placed approximately 6'-0" o.c. Drawings indicate that the braces are to be anchored into a bond beam, which runs along the top of the wall. However, observations show that, except for the cell that receives the brace, the top course is not grouted. Instead, the horizontal course one down from the top appears to be grouted. Consequently, the brace is cantilevered above the reinforced course. Small horizontal cracks were observed in some locations along the upper portions of this wall and are indicative of flexural cracks resulting from out of plane bending. Additionally, except for vertical dowels into the concrete slab, drawings indicate that no vertical reinforcement is present in the walls.

b. At the south stair of the offices, steam piping is present in the ceiling at the 3rd floor that leads to the underside of the skywalk. Please see the Piping section below for
additional discussion. Also, a plaster ceiling is attached to the concrete directly above the stairway at the 4th floor and shows signs of deterioration and water damage.

c. Consistent with other ceiling areas, lay-in ceiling tiles are not secured from falling along the corridors and means of egress.

d. A concrete skywalk provides access to the fourth floor of the services building. It was noted during our walkthrough of the building that the precast concrete guardrails along the skywalk could be rocked with relatively little effort. This raises concerns regarding the adequacy of the panel anchorage to resist seismic shaking. Although beyond the scope of this report, it is recommended that these panels be investigated further, as they may pose a falling hazard both to people on and below the walk.

e. The skywalk rests on bearing pads and brackets at the south face of the Services/Parking 2 Building. No visible means of restraint could be ascertained.

• Building Contents and Furnishings
  a. Tall narrow (height-to-depth ratio greater than 3) storage racks, bookcases and file cabinets were not anchored to the floor or adjacent walls in a number of locations, including the new retail space. In some areas, such as the supply store and personnel office, proper anchorage was noted on at least a portion of the bookcases and storage racks. However, even in these areas some unbraced bookshelves were noted in corridors and a number of storage racks in the storage areas were not braced and/or were not secured to the floor.
  b. Tall file cabinets were typically not restrained. In locations where groups of file cabinets are present, the cabinets may be attached to one another to increase their stability. All file cabinets should have latched drawers to ensure that they will remain closed during shaking.
  c. Items on shelves or storage racks are not restrained from falling. Although no particularly hazardous items were noted, falling contents can still pose a hazard to occupants. This includes things such as unrestrained standing lumber, piping, etc.

• Mechanical and Electrical Equipment
  a. For the most part, mechanical and electrical equipment is not anchored or braced. Mechanical blowers were outfitted with vibration isolators and minimal anchorage to the slab.
  b. Printing equipment in the new retail space was not anchored. This can be particularly problematic where large copiers on wheels are not restrained and are likely to travel in an earthquake, posing a risk to occupants.
  c. Standing electrical equipment was identified both in the garage and office areas. Proper anchorage to the slab at the base was not verifiable, though its presence seems unlikely.

• Piping
  a. Large piping is present in a number of locations, including mechanical rooms, garage drainage, fire suppression, etc. and lacks adequate bracing in nearly every occurrence. Typically, the FEMA Handbook recommends that piping 2 1/2” in diameter or larger be braced.
b. Fire suppression piping is sleeved in many locations to allow for differential movement, particularly in the vertical risers. However, instances were identified where stubs adjacent to sleeving penetrated a structural wall and were grouted solid. Correction of these types of inconsistencies should be reviewed and, if need be, corrected in conjunction with future upgrades.

c. Heat is provided by steam pipes that enter the building via the underside of the skywalk located to the south of the office. The interface between the skywalk and building represents a seismic joint. However, no flexible connectors in the piping were visible at the interface. Further, solid grouting is present as a separation, and only portions of the pipes are correctly sleeved.

d. No shutoffs were observed for the steam pipes entering the building at the skywalk. However, this would be a rather impractical location for shutoffs. Rather, it is likely that sufficient valves exist at the boilers located elsewhere on the campus.

- Ducts
  Large ductwork should be braced to resist seismic shaking. The larger ducts are located primarily in the main mechanical rooms and the basement portion of the garage. According to the FEMA document, ducts that are less than 6 square feet in area or less than 28” in diameter do not need to be braced. Consequently, much of the typical ductwork is adequate without special bracing. However, some of the smaller ducts providing ventilation for the lower garage area have a significant support length. This presents a concern since they may be susceptible to excessive movement and twisting similar to that discussed for the long-stem pendant lights. See above.

- Elevators
  Evaluation of the specific statements pertaining to elevators should be done by qualified personnel in conjunction with upgrading plans. The evaluation statements are listed in Section E of this report.

DEMAND vs. CAPACITY RATIOS

Using the analysis procedures discussed previously, lateral forces were distributed to the shear walls. Following the FEMA recommendations, a more precise wall capacity was calculated based upon current provisions of ACI 318, which is the basis for the present Uniform Building Code concrete sections. With this information, demand (De) versus capacity (Ce) ratios were calculated and are given in the tables that follow. The purpose of listing these ratios is to help identify the most stressed elements and, consequently, to lend some order to prioritizing corrections. However, it should be understood that other deficiencies can exist which are just as critical, or more so, though they are not evidenced in the demand-capacity ratios. A discussion of these deficiencies is presented in the next section.
DEFIENCIES AND POTENTIAL CORRECTIONS

The following paragraphs summarize the major deficiencies identified in the building and discuss, in broad terms, possible means for correcting them. Specific design and preparation of seismic upgrading and retrofit plans is beyond the scope of this report. Deficiencies are divided into two classifications, structural and non-structural.

Structural Deficiencies
1. A number of the shear walls, particularly in the garage, do not have sufficient capacity to resist the overturning forces resulting from lateral seismic loads. Primarily, the deficiency is a lack of tensile capacity. In addition, some walls lack proper boundary elements to confine high compressive stresses. Correcting these deficiencies can be accomplished in several ways. Applying exterior steel elements can provide tensile capacity and concrete boundary elements can be added to the ends. Alternatively, the
need for tensile and boundary elements can be mitigated by adding additional shear elements to help carry the load.

2. The irregular ‘L’ shape of the building introduces a tearing force at the inside corner. This problem is compounded by the discontinuous diaphragms that result from the misaligned levels between the office and garage portions of the building. There is potential for buckling of the common wall between these areas as a result of diaphragm deflection. Mitigating this problem is difficult. The solution will likely either require significant strengthening of the wall and diaphragm (e.g. drag struts) for out of plane forces, or the creation of a seismic separation between the two portions of the building.

3. Torsion, though not unmanageable, produces a sizeable increase in the overall shear forces resisted by a number of shear walls. This added load only magnifies some of the problems previously discussed. Obtaining a more balanced system, in terms of shear capacity and rigidity, would certainly aid in addressing some of the other deficiencies.

4. A 2" seismic joint separates the adjacent Campus Ministries building from the Services/Parking 2 building. With the increased seismic loads anticipated by recent codes, larger than expected deflections may result in pounding between the two structures. Without knowing more about the adjacent structure, it is difficult to know with certainty how significant (if at all) this deficiency might be. If determined to be a significant problem, correction would either require that one or both structures be stiffened to limit deflections, or the size of the seismic joint be increased.

Non-structural Deficiencies
5. The interior metal stud and gypsum board partition walls are connected to the suspended ceiling system and do not brace back to the structure. Consequently, in an earthquake, lateral load from these walls will be transferred to the ceiling system (the walls span between the floor and ceiling) which is not designed for this load. This can result in failure of the ceiling either through buckling or excessive deflections. Falling ceiling tiles can injure occupants and block means of egress. The most critical areas are longer wall segments. Small offices are less of a concern because their "box" configuration provides some degree of stability, though they still need to be braced.

6. In many areas, mechanical and electrical equipment, piping, conduit, and ductwork lack proper bracing or restraint. Proper anchorage should be provided for larger equipment, and necessary bracing should be provided for larger pipes (2 1/2" or greater) and ductwork (greater than 6 square feet or 28" in diameter) in accordance with current mechanical, electrical, or plumbing codes and practice. Lighting and mechanical fixtures should be secured independently of the ceiling system. Long pendant fixtures should be secured to limit deflections and equipped with diffusers. At the exterior, proper reinforcement and anchorage of the adjacent chimney should be investigated to ensure that it would remain intact during an earthquake.

7. The skywalk providing entry to the 4th floor of the Services/Parking 2 Building raises several concerns regarding safety, particularly as a means of egress. The precast concrete
handrails appear to be rather flimsy and may have a potential to fall. Also, support of the
walk at the face of the building had no visible means of restraint. It is recommended that,
if indeed there is no restraint, mechanical restraints be installed to limit travel and ensure
that the walkway remains on its supports in an earthquake.

CONCLUSIONS

Determining a precise quantitative level of risk for a given structure is beyond the scope of
analysis and evaluation for a FEMA-178 report. However, a qualitative assessment of the
building, in our opinion, places the garage in a moderate category, and the office in a low
category of risk for considerable damage resulting from a significant seismic event.

The most significant deficiencies in the building that may cause damage include a lack of
overturning capacity, excessive wall flexure resulting from discontinuous diaphragms,
problems associated with the irregular ‘L’ shape, and possible pounding with the adjacent
structure. Exceeding the overturning capacity is likely to result in flexural damage to the
foundation and significant cracking of the wall. The diaphragm discontinuity, coupled with
the irregular shape has the potential to “tear” the building. If this occurs, pounding between
respective portions of the structure, as well as possibly the adjacent one, may lead to
localized collapses in these vicinities, particularly at the common wall between the office and
garage.

There were a number of nonstructural deficiencies identified. Chief among these is a lack of
adequate bracing. Interior gypsum partition walls are attached to the suspended ceiling.
Neither is braced. For the most part, none of the mechanical, electrical or pipes are braced
for lateral loads. Similarly, in a number of areas, contents, including bookcases, storage
racks, and file cabinets are not properly secured. The same may be said along corridors and
means of egress where they carry an increased degree of importance. Yet, while these
elements in themselves typically do not represent a significant and direct threat to life safety,
indirectly, failure of nonstructural elements can block means of egress or trap people, thereby
precipitating potentially more serious consequences.