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Vicki S. McConnell, State Geologist

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PORTLAND STATE UNIVERSITY MONTGOMERY COURT SEISMIC REHABILITATION PROJECT, PORTLAND, OREGON

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EXECUTIVE SUMMARY

This case history summarizes the seismic upgrade project of the 1916 Montgomery Court residence hall at Portland State University (PSU) in Portland, Oregon. Montgomery Court, which is a four-story plus basement college dormitory, was designed by architect A E. Doyle and constructed of unreinforced masonry (URM). URM buildings are notorious for their poor seismic performance and are not allowed by the current Oregon building code. The roof level of this building contains many falling hazards such as parapets, ornaments, and chimneys that are a threat to individuals passing by the building. In 1997, this building was evaluated (using the Federal Emergency Management Agency [FEMA] 178 methodology), and many serious structural deficiencies were found to pose a serious life safety threat to over 150 student residents. Corrective action was recommended.

In April 2004 the Oregon Department of Geology and Mineral Industries (DOGAMI) was funded $780,000 by the U.S. Department of Homeland Security FEMA Predisaster Mitigation Program (PDM) to conduct a partial seismic upgrade. The FEMA grant provided 75% of the mitigation cost. The remaining 25% was funded by the state — the Oregon University System (OUS) and PSU. Oregon Emergency Management (OEM), which administers FEMA PDM grants for the state, provided administrative contract assistance between DOGAMI and FEMA. Actual costs for seismic rehabilitation were approximately $640,000, about $140,000 lower than the estimated $780,000. The rehabilitation was successfully completed in December 2005.

The mitigation, which complied with state historic preservation guidelines, improved connections and ductility of the building, strengthened egresses and secured falling hazards. These major improvements are intended to upgrade the building to a collapse prevention performance level and to minimize the potential for a collapse of the entire building. The mitigated building does not, however, meet life-safety standards.

The Montgomery Court upgrade was a high-visibility demonstration project. This project helped raise earthquake hazard awareness on campus, in the community, and in the state, including among influential state leaders. This project has helped establish a firmer foundation for more seismic mitigation of high-risk educational facilities.

INTRODUCTION

Oregon is characterized by a beautiful and geographically diverse landscape. However, the geology responsible for this landscape is associated with a variety of natural hazards. Earthquake hazards are a significant threat for the entire state, but especially in the western portion. While seismic risk is considerably higher in California than in Oregon, actual life safety risk is higher in Oregon due to the percentage of structures that are not earthquake resistant.

Portland, Oregon, home to Portland State University (PSU), is located approximately 100 miles east of the Cascadia Subduction Zone fault, which has the potential of producing an earthquake similar to the magnitude 9.1 December 26, 2004, Sumatra earthquake and Indian Ocean tsunami. Furthermore, the Portland Hills fault is a threat because it runs very near the PSU campus. The U.S. Geological Survey (USGS) projects significant earthquake ground shaking levels in the Portland region with a 2% chance in the next 50 years that bedrock ground shaking levels will exceed about 0.4g (USGS, 2003). Many PSU buildings were not originally designed and constructed to withstand this level of ground shaking.

Because Oregon faces a serious statewide threat from earthquakes, federal, state, and local governments and private organizations have been supporting earthquake risk reduction. Oregon has made significant strides in reducing adverse impacts of earthquakes on Oregon schools, including successful mitigation and rehabilitation of a limited number of Oregon's seismically deficient school buildings.

The seismic rehabilitation of Montgomery Court residence hall at PSU (Figure 1) is an example of a successful mitigation project.

Figure 1. Montgomery Court residence hall on the Portland State University campus. Photo taken from the northwest.

EARTHQUAKE AWARENESS FOR OREGON UNIVERSITY BUILDINGS

Oregon leaders have recognized the importance of seismic safety in public school buildings. In 2001, the Oregon Legislature passed a state law (Oregon Revised Statute 455.400; http://www.leg.state.or.us/ors/455.html) that requires public school buildings with 250 occupants or more to meet life-safety standards. In 2002, Oregon citizens voted statewide to amend the Oregon constitution to allow the Oregon Legislature to establish general obligation bonds to provide funds to rehabilitate school buildings, including university buildings. In 2005, the Legislature passed bills authorizing the Department of Treasury to issue state bonds to mitigate high-risk educational buildings.

Oregon University System (OUS) is committed to rehabilitating seismically deficient university buildings. The Oregon Department of Geology and Mineral Industries (DOGAMI) has been working with OUS since 2002 to complete a seismic risk study on all the facilities at the state's seven public university campuses. In 2002 and 2003, DOGAMI and OUS assessed the seismic needs of OUS buildings and developed a strategy for long-term planning. An evaluation of approximately 1,000 buildings was conducted (Simonton and others, 2004).

DOGAMI developed a six-step method (Figure 2) for OUS, which is part of the long-term mitigation plan (Wang, 2004). The six-step method incorporates a rapid visual screening (RVS) method, structural engineering and benefit costs analyses, deferred maintenance and energy efficiency needs, and other considerations. In 2005 and 2006, DOGAMI codeveloped a preliminary enhanced RVS (E-RVS) method, which is being used by OUS (Wang and Goettel, 2007).

FEMA GRANT AWARDS

Out of about 1,000 buildings, OUS and DOGAMI identified Montgomery Court along with PSU's Ondine residence hall and the Oregon Institute of Technology's (OIT) Snell Hall as the top candidates for seismic rehabilitation. Many other university buildings that were not selected for this grant proposal have serious seismic deficiencies.

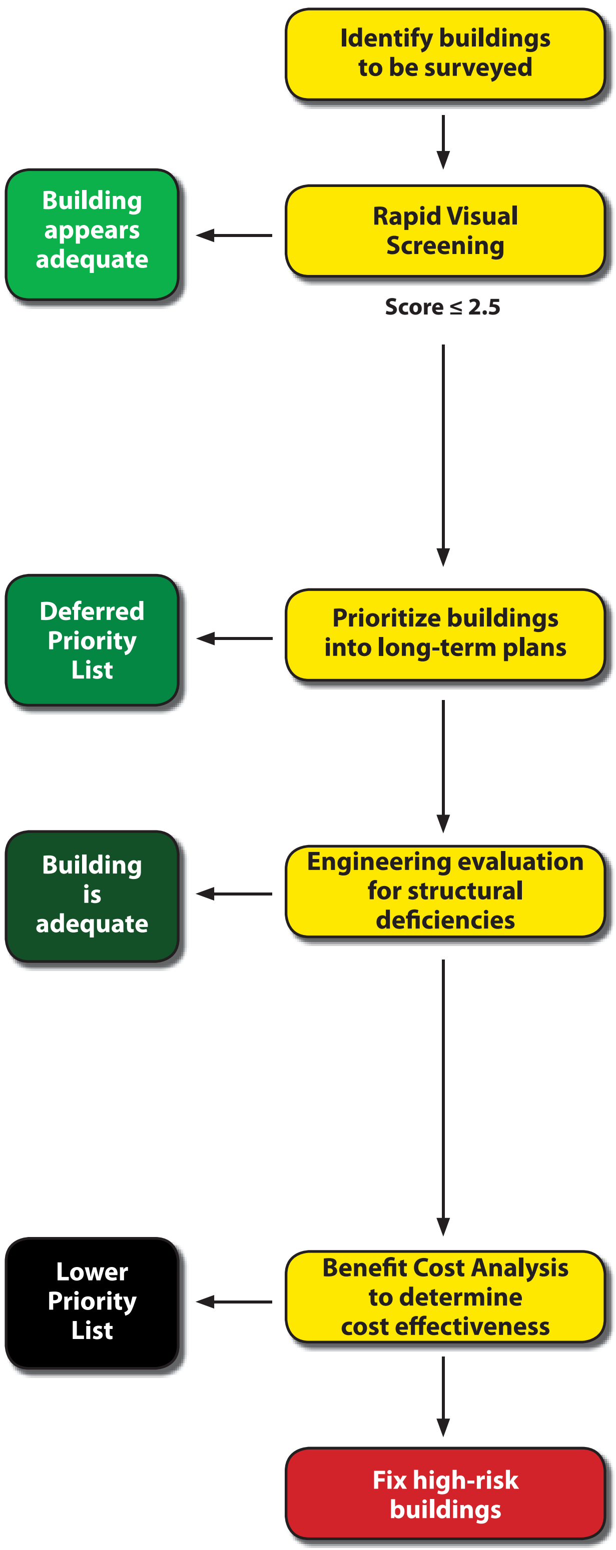
In selecting Montgomery Court, DOGAMI collaborated with PSU's Michael Irish (retired Director of Facilities), Richard Piekenbrock (former Campus Architect), Carol Hasenberg (former structural engineering instructor) and Robert Simonton (OUS). Once Montgomery Court and the other buildings were selected, DOGAMI and OUS worked together to complete a competitive FEMA Pre-disaster Mitigation Grant (PDM) application. The grant was submitted with two letters of support from structural engineers from PSU and Oregon Seismic Safety Policy Advisory Commission (OSSPAC). The comprehensive grant proposal, which included engineering evaluations, benefit cost analyses, and stakeholder support, was judged to be nationally competitive.

In April 2004 FEMA provided DOGAMI a $3.8 million award described as an earthquake building rehabilitation grant. FEMA funding provided 75% of the budgeted total project costs of approximately $3.8 million to complete the seismic readiness work on the three buildings. OUS committed to the match amount of almost $950,000 (25% of the total) required by FEMA to receive the grant monies. The funds were allocated to upgrade the buildings as "demonstration projects," further described below. Oregon Emergency Management (OEM) provided state assistance to DOGAMI and the overall project.

MONTGOMERY COURT RESIDENCE HALL

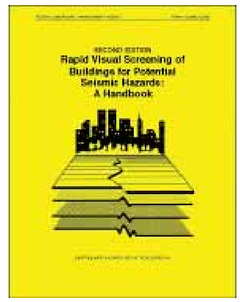
Montgomery Court, which is located at 1802 SW 10th Street in Portland, was constructed in 1916 as a four-story plus basement unreinforced masonry (URM) structure by architect A. E. Doyle. In 1925 an additional wing with URM construction was added. Although this building is not registered with the State Historic Preservation Office (SHPO), Montgomery Court is deemed important from an historical and architectural standpoint. Thus, the seismic rehabilitation project was conducted in accordance with SHPO regulations.

URM buildings have performed poorly in past earthquakes, resulting in collapse or very serious damage. URMs typically have distinct features including arched windows and a header course of bricks. A header course is a layer of bricks perpendicular to the wall, usually spaced every six to seven rows. The header course ties the back lathe of bricks to the front lathe, providing some limited structural integrity for the wall. In contrast, a header course is not necessary for reinforced masonry construction because steel reinforcement is provided to tie the wall together.



Step 1. Planning Stage
Identify buildings to be surveyed. Buildings with 24/7 or high-capacity occupancy (Oregon Revised Statute 455.400) hazardous materials, critical operations, and special concerns.

Step 2. Rapid Visual Screening (RVS)
Conduct FEMA 154 screenings to develop preliminary scores (e.g., earthquake performance) and preliminary funding needs.



Federal Emergency Management Agency (FEMA) 154 — Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook

Step 3. Prioritization
Prioritize buildings that warrant detailed engineering studies. If building scores ≤ 2.5 AND requires additional upgrades, then engineering evaluations are recommended. Prioritization factors involve: seismicity, occupancy load, energy efficiency, deferred maintenance needs, Americans with Disabilities Act regulations, fire safety, environmental condition, modernization, and special circumstances (e.g., historic, shelter, future demolition).

Step 4. Engineering Evaluation
Conduct ASCE 31 engineering evaluations to determine any specific seismic deficiencies and mitigation concepts.

American Society of Civil Engineers (ASCE) 31 — Seismic Evaluation of Existing Buildings

Step 5. Benefit Cost Analysis (BCA)
Conduct BCA to determine cost effectiveness of mitigation. If the benefit cost ratio (BCR) exceeds 1, then mitigation is recommended.

Step 6. Earthquake Mitigation
Mitigate high-risk buildings with BCR > 1 to improve life-safety, liability, and sustainability. Level of upgrades varies. Use FEMA 356 method or other appropriate method.

Figure 2. Six-step evaluation method for high-risk buildings developed by the Oregon Department of Geology and Mineral Industries for the Oregon University System.

Arched windows in older brick buildings indicate that the building is likely to be a URM because a window is not strong enough to support heavy bricks stacked on top of it. An arched pattern of bricks above the window prevents the wall from collapsing downward into the open window space. Figure 3 shows the typical features of a URM building.

Montgomery Court is a 52,500 sq-ft, U-shaped building and houses about 150 students year round. The building also contains administrative offices for College Housing Northwest on the first floor as well as space for other university entities.

Montgomery Court was determined to have serious deficiencies and potential for complete collapse during the next major seismic event. It was identified as a high-priority building to rehabilitate on the basis of year-round student occupancy and URM construction type. Furthermore, this building is an integral part of the PSU community: it is a public service building, houses students, and has historical value. If this building were damaged and became dysfunctional following a seismic event, the entire community would be negatively impacted. In addition, the building is adjacent to a major pedestrian walkway, and the unusually tall, unreinforced masonry parapets posed a significant falling hazard.

DEMONSTRATION PROJECTS AT OREGON UNIVERSITIES

Researchers have found that supporting seismic mitigation activities increases the resilience of communities by increasing knowledge and promoting institutional commitments to mitigation at the local level. Mitigation is most effective when it is carried out on a comprehensive, community-wide, long-term basis. Single projects help, but carrying out a slate of coordinated mitigation activities over time is the best way to ensure that communities will be physically, socially, and economically resilient in coping with future earthquakes (NIBS, 2005).

Mitigation activities can be divided into two types: project and process. Project mitigation includes physical measures to avoid or to reduce damage from earthquakes; process mitigation includes activities that lead to policies, practices, and projects that reduce risk and loss. Typical process mitigation activities include vulnerability and risk studies, increasing awareness by decision makers, building constituencies, fostering adoption of mitigation strategies, adopting building codes for existing buildings, and conducting synergistic activities (NIBS, 2005).

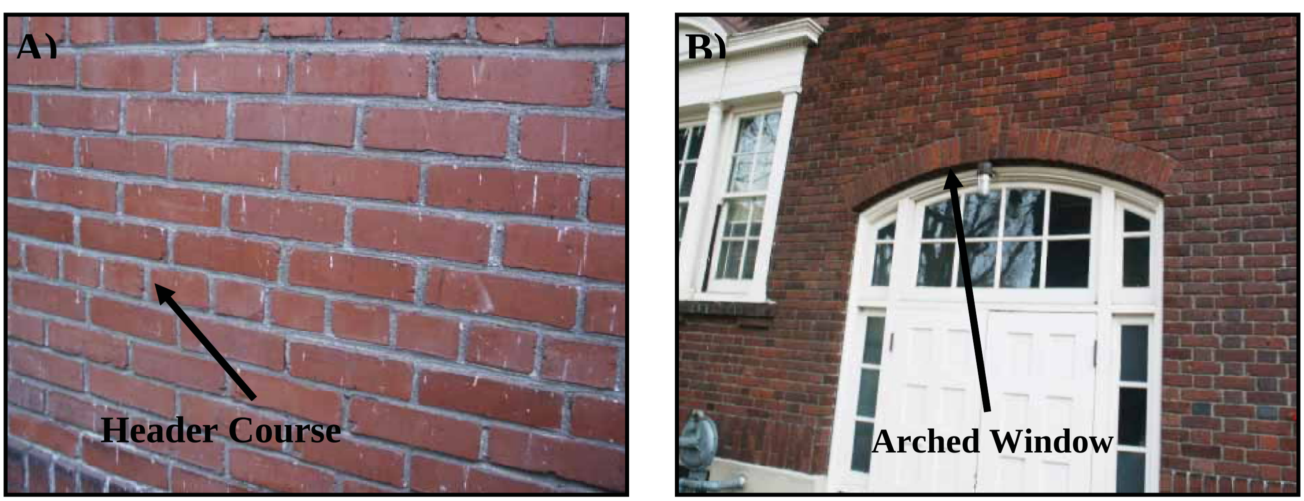


Figure 3. Typical features of unreinforced masonry construction. (A) header course (B) arched windows.

Oregon has five demonstration projects at university campuses: Montgomery Court and Ondine Residence Hall at Portland State University, Snell Hall Administration Building at the Oregon Institute of Technology, Humanities and Social Sciences at Western Oregon University, and Nash Hall at Oregon State University. These demonstration projects are considered to include typical project mitigation benefits, but also include a strong component of process mitigation. Project mitigation benefits are due to losses avoided relating to:

- Reduced direct property damage, including buildings, contents, and the building's lifeline services connecting to adjacent facilities
- Reduced direct "business" interruption loss, including campus operations, classroom activities, and research activities
- Reduced human losses, including deaths, injuries, and homelessness (for residence halls)

Oregon's demonstration projects involve or will involve process mitigation activities, including:

- Reduced cost of emergency response, such as ambulance service, fire protection, and environmental cleanup
- Reduced indirect business interruption loss, including ripple effects such as loss of housing income, enrollment, or research status
- Societal impacts, such as increased awareness among decision makers and peace of mind within the community at large
- Synergistic impacts, such as future project mitigation, further discussed below

According to Robert Simonton, Director of Capital Construction for OUS, receiving the 2004 FEMA grant has allowed OUS to increase the safety of campus facilities by increasing earthquake awareness among decision makers and university facilities staff. OUS campuses make up half of all state-owned facilities in Oregon and have a decade-plus deferred maintenance backlog of approximately $600 million. In 2005, the Oregon Legislature approved a spending limitation of $410 million for capital repair, maintenance, and new construction. At the same time, OUS has been making significant progress on addressing seismic upgrades to improve campus safety. OUS was allocated $8 million in state funds as the first systematic allocation for university seismic needs by the state.

When FEMA grants lead to additional non-federally funded mitigation activities and help institutionalize seismic mitigation programs, the benefit-cost impacts are substantial and highly cost-effective for the state. The five university demonstration projects will result in future savings by averting casualties and by reducing direct financial losses due to building damage, increasing continuity of university operations, and increasing campus preparedness. Moreover, long-term mitigation strategies are being considered or are being improved at the campuses.

Oregon's long-range goal is to upgrade all public school buildings, including university buildings, to life-safety standards as mandated by the 2001 laws. These five university seismic upgrades will serve as demonstration projects to meet the 2001 laws not only in the community but to the Oregon government and legislators as well. These projects have been strongly supported by various earthquake policy and engineering organizations, including OSSPAC, the Oregon Department of Emergency Management (OEM), and various other institutions.

MONTGOMERY COURT AS A DEMONSTRATION PROJECT

The rehabilitation of Montgomery Court has served as a demonstration project for awareness of seismic safety for Oregon's school buildings. The project has gained visibility throughout the state because of its geographic location and because of the diverse student population and associated activities. Furthermore, as part of the project management tasks, the project gained media visibility on campus, in the Portland region, in the state, and elsewhere. Campus newspapers, radio stations, and online reporting have increased the awareness of this project. The local community and the state have also gained awareness through television, radio, newspaper press, and meetings. This includes press coverage in the *Oregonian*, *Daily Journal of Commerce*, Oregon Natural Hazards Workgroup's *Partnerships in Action* newsletters, PSU *Daily Vanguard*, Structural Engineering Association of Oregon newsletter, American Society of Civil Engineers newsletter, and more. This demonstration project was presented at meetings of Oregon's Interagency Hazard Mitigation Team, the Oregon Seismic Safety

Policy Advisory Commission, the 100 Year Anniversary Conference on the 1906 Earthquake cosponsored by the Earthquake Engineering Research Institute, the American Society of Civil Engineers national conference, and to other interested groups.

Representatives from FEMA, as well as a host of other agencies and organizations, were invited to tour the building during the construction phase in August 2005. High-ranking officials, such as PSU President Dan Bernstine, as well as community and project team members participated in the tour (Figure 4).

It is important to provide awareness of demonstration projects not only during the planning and construction phases but also long after construction is complete. Therefore, each of the five university demonstration projects includes or will include a permanent public display to provide earthquake safety awareness. At Montgomery Court, a commemorative plaque was erected at the main building entrance to serve as a reminder of the recent seismic upgrades. A schematic of the plaque is shown in Figure 4 (inset).

Initial Seismic Evaluations

In 1997, KPFF Consulting Engineers was retained to conduct a general structural seismic evaluation of the Montgomery Court building using the FEMA 178 methodology (FEMA, 1992). The scope of KPFF's review was limited to only the structural elements resisting lateral forces and potential life safety hazards, such as significant falling hazards.

On May 12, 1997, KPFF engineers conducted a site visit. The purpose of the site visit was to observe the general condition of the building, to review the available design drawings, and to establish an assessment of the most significant structural deficiencies (KPFF, 1997).

KPFF identified that lateral earthquake forces were resisted by URM perimeter shear walls within the building. The walls are generally broken up by windows or doors into wall piers. Each pier at a particular floor resists a portion of the accumulated story forces relative to its stiffness. KPFF determined that the demand on the masonry piers is likely to be higher than current capacity.

Figure 4. Portland State University (PSU) August 2005 seismic mitigation tour. Participants included Portland State University (PSU) President Dan Bernstine; PSU Facilities and Planning Director Robyn Pierce; Federal Emergency Management Agency (FEMA) Region X representative Sharon Loper; Oregon Emergency Management (OEM) representative Abby Kershaw; Robert Simonton, Oregon University System (OUS) Director of Capital Construction Planning and Budget; and James Doane, chairman of the State Earthquake Commission. Also present are Oregon Emergency Management staff, PSU facilities and housing departments staff, PSU Civil and Environmental Engineering department faculty, Oregon Department of Geology and Mineral Industries staff, community leaders, and project team leaders (architect, construction manager, and general contractor). Inset: Demonstration project plaque for Montgomery Court seismic retrofit.

KPFF's findings indicated that the existing roof was completely unanchored and that the fourth floor ceiling was poorly anchored with unbraced, unsheathed pony walls connecting the roof and ceiling framing. Also, using the 1997 Uniform Building Code methods (ICC, 1997), the design level force on the wall anchors was determined to be inadequate. In addition, the roof parapets and other falling hazards such as chimneys and ornaments were poorly attached, and it was estimated that little or no lateral support would be available to prevent them from falling to the ground below. KPFF's findings suggested seismic rehabilitation was needed. However, until the FEMA PDM grant funding became available, no additional work or studies were completed on the building.

SEISMIC MITIGATION DESIGN DEVELOPMENT

Upon approval of the FEMA PDM grant funding, the PSU facilities and planning department began project scoping activities. It was verified that it would not be cost effective to rehabilitate the entire URM structure. The focus was to determine how to best conduct a partial rehabilitation to significantly improve life safety. As preserving the historic architectural features in accordance to SHPO standards was considered to be important, mitigation options were limited.

Figure 5. Exploration of the top diaphragm connections in attic space below the roof.

WDY Structural and Civil Engineers was hired by PSU to determine appropriate mitigation solutions. The attic space was explored, and it was confirmed that the top diaphragm was not adequately connected to the URM walls (Figure 5). Stairwell walls were examined, and it was determined that there was little or no support available to prevent collapse during a seismic event. This was a major concern because available egress must be available for safe evacuation directly following an earthquake. Because the roof, walls, and high parapets were not structurally tied together, they would likely be damaged if they were not strengthened. Ultimately, it was decided to address significant weaknesses in the parapet bracing, roof anchorage, roof diaphragm improvements, chimneys, and selected architectural features.

WDY proposed solutions based on the FEMA 356 methodology (FEMA, 2000). The solutions were intended to provide general improvements to serious deficiencies in order to achieve a collapse prevention performance level where "the building remains standing but only barely and any other damage or loss is acceptable" (FEMA, 2000). Although this mitigation is considered to be a low level of performance, it substantially increases life-safety conditions during a seismic event. The basic seismic rehabilitation design included four mitigation measures:

1. Tying the top diaphragm and walls to a new roof,
2. Anchoring the falling hazards,
3. Securing the parapets, and
4. Adding reinforcement to the stairwells.

MITIGATION COSTS

The final project costs were about \$640,000, \$140,000 under the original \$780,000 budget. Table 1 summarizes project costs, including construction costs and the soft costs, such as project management, design, engineering, permits, and inspections.

The PSU project manager, architect Francis McBride, determined that mitigation work beyond what WDY proposed would not be cost-effective ; thus costs were below the original budget. Also, McBride estimated that approximately \$10,000 was saved by keeping the project management duties within the PSU Facilities and Planning Department rather than outsourcing it.

All project costs were directly related to seismic improvements. The existing roof was not adequate to tie into the URM walls and required replacement, although, according to McBride, a roof replacement would not be needed for a few more years.

Some minor non-seismic modernization improvements, such as carpet replacement, were made necessary due to the seismic mitigation. Carpeting was replaced only in rooms where it was necessary to remove a portion of the floor to complete the reinforcement work on nearby stairwells.

Table 1. Approximate cost summary for Portland State University Montgomery Court seismic rehabilitation project.

Construction Costs	
$290,000	re-roofing parapet bracing straps penthouse
$100,000	stairwells (3) framing steel reinforcement
$70,000	front and back porches
$35,000	fire escape improvements
Soft Costs	
$33,000	architect structural engineer special inspection consultant asbestos inspection/monitoring
$65,000	PSU facilities, College Housing Northwest OUS and DOGAMI
$20,000	permits, bonds, surcharges, archiving
$27,000	temporary relocations moving expenses food vouchers
$640,000	Total

SEISMIC MITIGATION CONSTRUCTION

After the FEMA PDM grant was awarded in spring 2004, PSU Facilities and Planning Department integrated the rehabilitation project into their schedule. In 2005 the complete project team was assembled. Construction for the seismic mitigation occurred in summer 2005. The project team, project schedule, and mitigation are discussed in this section.

Project Team

PSU Facilities and Planning Department managed the project and assembled the project team. PSU conducted the architectural design work in collaboration with WDY, the structural engineering consultant. WDY completed the construction documents and architectural drawings. Paul Edmund, a consultant, was hired to complete the project specifications. Fortis Construction was the general contractor. College Housing Northwest, which operates campus student housing including Montgomery Hall, worked with PSU and represented the building occupants. DOGAMI was the project facilitator and organized two demonstration tours. DOGAMI and OEM provided oversight and administrative assistance, respectively. Project team members and their roles are summarized in Table 2.

Project Schedule

PSU Facilities and Planning considered the academic schedule in developing the project schedule. The project was planned so that all construction activities would take place during the summer after the Spring quarter finals were completed. Although the building was to remain fully occupied, only minimal disruption would occur in the main academic year. The project schedule and a time line of major events are given in Table 3.

To accommodate the tenants, a notification system was devised to alert affected residents 48 hours in advance that they would need to vacate during normal business hours. In addition, weekly notices were posted for areas in the building likely to be affected by construction noise and odors (e.g., from asphalt). This plan worked out for the most part. However, as with all projects, some errors were made. In this project the notification system did not completely succeed. This issue is considered in the section "Discussion and Lessons Learned" in hopes that future projects can benefit from it.

Table 2. Portland State University Montgomery Court seismic rehabilitation project team.

Role	Member	Location
Owner	Portland State University	Portland
Operator	College Housing Northwest at PSU	Portland
Architect	Francis McBride, PSU Facilities and Planning	Portland
Structural Engineer	WDY Consulting Engineers	Portland
Specifications Consultant	Paul Edlund, FCSI	Portland
General Contractor	Fortis Construction	Portland
Project Funding	U.S. Department of Homeland Security - Federal Emergency Management Agency	Washington, DC
	Oregon University System	Oregon
	PSU Facilities and Planning	Oregon
	College Housing Northwest	Oregon
Project Facilitator/Oversight	DOGAMI	Oregon
Administrative Assistance	Oregon Emergency Management	Oregon

PSU is Portland State University; DOGAMI is Oregon Department of Geology and Mineral Industries.

Table 3. Portland State University Montgomery Court seismic rehabilitation project schedule and time line of major events.

Time Period	Event
1916	Original construction of Montgomery Court
1925	New building wing added to Montgomery Court
1974	Oregon adopts first statewide building code
1994	Oregon adopts significant seismic upgrades in statewide building code
2001	Oregon Legislature passes legislation in support of earthquake safety for schools
2002	Voters approve general obligation bonds for earthquake safety in schools
2002	DOGAMI and OUS partner to assess seismic vulnerability of university campuses
2002-2003	DOGAMI and OUS partner to write FEMA Competitive Grant Proposal
September 2003	DOGAMI submits Predisaster Mitigation Grant Proposal
April 2004	FEMA awards competitive grant for rehabilitation of Montgomery Court residence hall
January to May 2005	Project planning and preconstruction design; contractor/subcontractor bids and awards
April 8, 2005	Seismic mitigation tour #1
April to June 2005	Permits and bidding for construction
June to September 2005	Construction of seismic strengthening
August 10, 2005	Seismic mitigation tour #2
September to November 2005	Finishing/ Architectural work
December 2005	Final on-site inspection by OEM and others

DOGAMI is Oregon Department of Geology and Mineral Industries; OUS is Oregon University System; FEMA is Federal Emergency Management Agency; OEM is Oregon Emergency Management.

Four-Part Mitigation

Seismic mitigation included (1) tying the top diaphragm and walls to a new roof, (2) anchoring the falling hazards, (3) securing the parapets, and (4) adding reinforcement to the stairwells. Each part of the seismic mitigation is discussed.

Mitigation 1: Tying the top diaphragm and walls to a new roof

One of the basic principles of seismic structural design is to provide adequate connections between the vertical and horizontal structural elements so that earthquake forces can be accommodated by the structure. For this project, tying the upper portion of the building together was the major structural improvement to prevent a catastrophic collapse. Figure 6 shows construction photos of the new roof and new vertical to horizontal member connections.

The top diaphragms (horizontal member) were tied in at both the roof and the ceiling of the fourth story. Long mechanical anchors with threaded steel rods were used to secure the new roof joists to the URM walls. Couplers were used as necessary to connect individual threaded rod segments. Epoxy-coated anchor bolts were installed to connect the steel rods to the existing URM walls. A new structural plywood roof was placed on top of the existing roof deck. The new roof was required for adding new anchors to secure the parapets and falling hazards, such as ornaments and the URM chimneys. New sheathing was also installed along the entire surface of the roof, including the access tower.

Figure 6. Construction activities on the roof of Montgomery Court. (A) tying the diaphragm into the existing unreinforced masonry wall, (B) installation of long mechanical anchors with anchors and threaded steel rods, (C) placement of structural plywood, and (D) new roof sheathing.

Mitigation 2: Securing the parapets

The existing URM parapets, which are about 6 feet tall, were secured at the roof level around the perimeter of the building to mitigate a major falling hazard. Figure 7 shows the construction materials used for securing parapets.

Steel angle members were used to brace the parapets to the existing roof joists. Specifically, a portion of the roof was removed around the entire perimeter in order to expose existing wood joists. Epoxy-coated, ¾-inch anchor bolts were used to connect the steel bracing to parapets, and 6-inch-long lag bolts were used to connect to the existing joists. The anchors were spaced at 48 inches on center. In a few locations due to special circumstances, it was necessary to use a longer spacing of 60 inches.

The steel bracing was covered with ½-inch plywood sheets on a diagonal. Then, new roofing material was applied to provide corrosion protection. This covered configuration is easier to maintain and eliminates the possibility of individuals tripping on the new bracing. Small, 2-inch thick, wood support blocks were nailed to the roof and anchored to the parapets in order to connect the plywood sheets to the existing roof and parapets. Two-inch nails were used at regular spacing to connect the plywood sheets to the wood blocks.

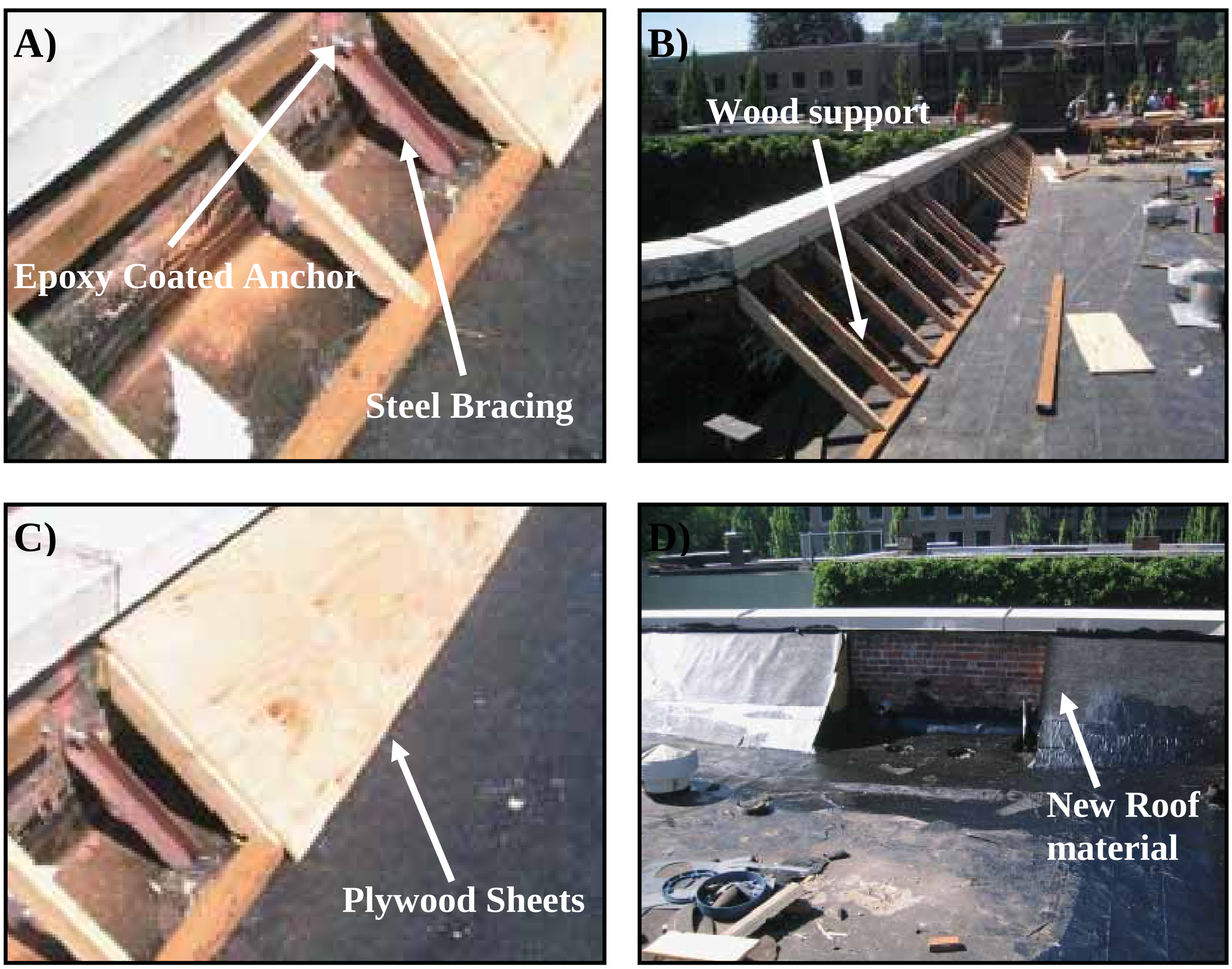


Figure 7. Construction materials used for securing the unreinforced masonry parapets on the roof of Montgomery Court.

Mitigation 3: Anchoring the falling hazards

In addition to the tall URM parapets, Montgomery Court includes a variety of other falling hazards. The more notable falling hazards include several concrete ornaments and an URM chimney. Figure 8 shows the bracing used to anchor falling hazards.

The falling hazards were secured at the roof level around the perimeter of the building. Standard 2½-inch diameter galvanized steel pipe was used to brace these features to the existing roof joists. As with the parapet mitigation, a portion of the roof was removed around the entire perimeter in order to expose existing wood joists. Epoxy-coated anchor bolts were then used to connect the galvanized steel pipe to the falling hazards, and 3/8-inch bolts were used to connect to the existing wood joists.

Mitigation 4: Adding reinforcement to the stairwells

It is critically important to maintain clear, usable egress after an earthquake, especially in URM buildings, which are expected to incur damage. Before mitigation, Montgomery Court had three structurally inadequate stairwells serving as exit paths. For this project, the walls in each stair towers were reinforced by installing structural walls next to the existing walls. Steel bracing was also added for two of the stairwells. In these cases, tube steel was epoxy anchored into the URM wall, and steel straps were bolted to the wood. Figure 9 shows construction of stairwell reinforcement.

Figure 8. Bracing used to anchor falling hazards on the roof of Montgomery Court: (A) chimney and (B) ornament bracing.

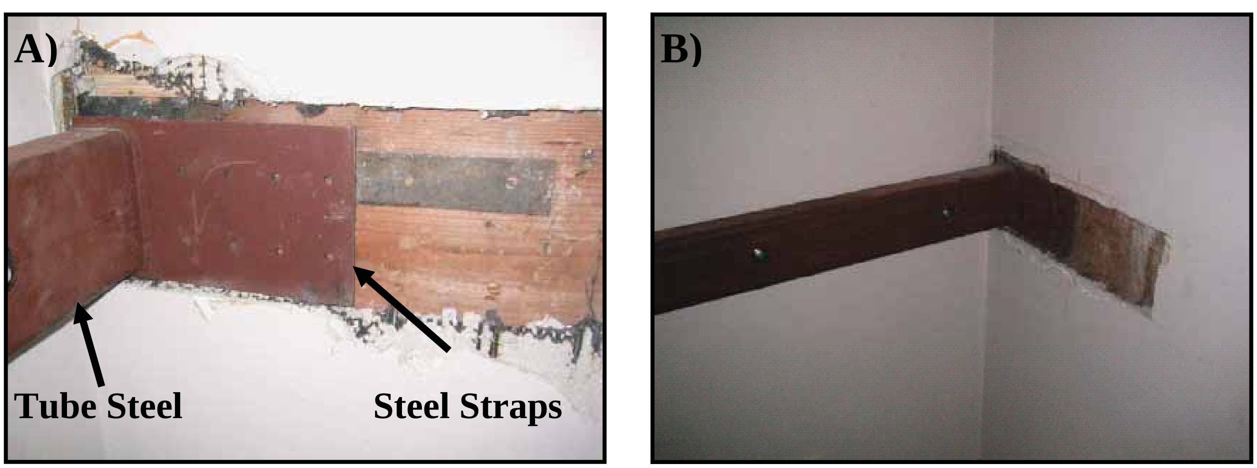


Figure 9. Construction of stairwell reinforcement in Montgomery Court. (A) close-up of tube steel and steel straps, and (B) broad view of stairwell reinforcement at corner.

Most of this work was conducted in the stairs or adjacent corridors. However, it was necessary to mitigate some of the walls in the apartment units adjacent to the stairs. In these cases, it was necessary to remove the trim on the affected wall in the unit and construct a new wall adjacent to the existing wall. New walls were finished with new paint and trim.

DISCUSSION AND LESSONS LEARNED

Recent studies indicate that Oregon is at risk for a major earthquake. In addition to the Cascadia Subduction Zone threat, many communities also have active crustal faults nearby that pose a real threat. Oregonians have expressed a strong concern about Oregon's earthquake risk and want to improve the state of readiness. As a consequence, to better prepare and protect Oregonians from future earthquake losses, the state's goal is to increase awareness and promote preparedness through demonstration projects such as Montgomery Court.

In order to ensure that Oregon is better prepared for damaging earthquakes, state agencies, the federal government, and the private sector must work together to meet long-term mitigation goals. The seismic rehabilitation of PSU's Montgomery Court contributes to meeting these state goals and serves as a demonstration project to create momentum in earthquake preparedness throughout the state. Thus the rehabilitation is not only a demonstration project on the PSU campus but also as an impetus for individual owners and communities to conduct similar seismic retrofit projects.

As with other seismic upgrade projects, several major issues arose. A discussion of two issues is provided with the hope that others involved with seismic upgrades will be able to consider these issues and learn from them.

Montgomery Court is still vulnerable

One primary concern about Montgomery Court is that it remains vulnerable to significant damage in an earthquake due to its inherent structural deficiencies. This project upgrade provided partial mitigation, created a much safer structure for its occupants and nearby pedestrians, and will allow for egress following an earthquake. In addition, the upgrade was cost effective and the building's historical architectural features were preserved. The risk reduction upgrade, however, did not achieve a life-safety standard that is required by today's building codes. In fact, a URM building is not allowed to be built in today's building code. Thus, upgrading an existing URM to code is difficult. Although Montgomery Court is expected to perform poorly during a major earthquake, the building has been upgraded to avoid collapse (see Figure 10).

Despite these significant improvements, the structural brick walls were not improved and are considered to be "nonductile." Unless the brick walls are mitigated

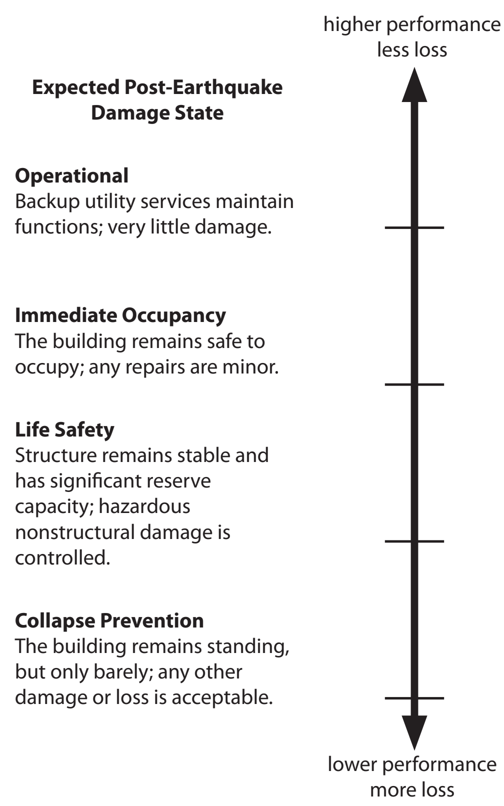


Figure 10. Building performance levels (FEMA, 2000).

for seismic performance, the building will remain will remain vulnerable to very serious damage during the next major seismic event. There are several possible mitigation methods, but none were deemed feasible for the Montgomery Court project due to the high costs and loss of historical architectural features. One method is to apply reinforced shotcrete or fiberwrap to the interior or exterior of the URM walls. Another method is to add reinforced concrete shear walls or steel-braced frames at the interior or perimeter of the building.

In the future, may be worthwhile to decrease the number of residents and occupants at Montgomery Court so that the building is occupied by fewer people for fewer hours.

Construction of occupied building

It is often difficult to conduct major construction activities to an existing building, especially when the occupants remain in the building. If the occupants are not relocated to another building, they can be inconvenienced from increased activity in and around the building, construction equipment and materials, safety issues, detours, noise, and dust.

When project meetings first began between PSU and Fortis Construction, there was concern about the safety of residents. The project team considered relocating some residents; however, it was ultimately decided that it would be too disruptive to move students. Overall, this decision appears to have been sound, but a few students were negatively impacted by construction activities. Brief descriptions of two understandable, yet avoidable, situations are provided so that others can learn from our mistakes.

One issue was that residents did not receive notice in advance of construction on a particular day. Residents of the fourth floor said that although work was scheduled directly overhead they had been given no notice until after construction had already started that they should leave their units (Baker, 2005).

Another situation involved damage to an interior apartment. On the morning of June 22, 2005, minor rain showers were expected. Construction workers removed the roof from an extensive portion of the Montgomery Court north wing, exposing insulation and ceiling joists. According to general contractor's project engineer, at around noon an unexpected storm hit central Portland, forcing workers to provide temporary protective roof covering. The contractor had a thick, plastic tarp on site. However, because the storm moved quickly, water had already seeped in before the tarp could be effectively applied. On June 28 after several hours of rain, a PSU student was studying in her apartment when stucco fragments and colored fluids fell on her sofa and other belongings (Baker, 2005). Although arrangements were made for her and a few other affected students to relocate to a nearby hotel, the poor communication and water damage left at least one student dissatisfied.

Construction on existing, occupied buildings is often complex, and being well prepared is important. For these types of construction projects, it is helpful to have good communication with the tenants during the planning stage and construction stage.

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