Oregon Schools Seismic Safety Project

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INTRODUCTION

The purpose of this project was to assist in the development of a statewide earthquake vulnerability analysis of Oregon schools and to use the results to prepare a mitigation planning methodology for use by school facilities personnel. Western Oregon has approximately 1,200 public schools in 173 districts. Historic earthquake activity, including recent damaging earthquakes in the Scotts Mills and Klamath Falls communities, and the results of earthquake studies by the Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Geological Survey (USGS), and other scientists indicate that western Oregon is an area of high earthquake hazard. Schools located in western Oregon are potentially vulnerable to earthquake-induced damage and associated human and economic losses.

The Oregon School vulnerability project was to be carried out in three phases: (1) develop a general screening tool to assess school earthquake vulnerability, (2) complete data analysis and validate study data collected in the general survey using detailed studies of representative districts, and (3) develop a methodology to assist school facility planners in the management of school mitigation projects. This report focuses on the progress made in phase 1. The Oregon Emergency Management and the Federal Emergency Management Agency provided funding for the completion of phase 1. Phases 2 and 3 were not funded.

Figure 1. Earthquake damage at Molalla High School from the Scotts Mills ("Spring Break") earthquake, March 25, 1993.

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BACKGROUND

The extensive Oregon public awareness program on regional earthquake hazards and their potential impact on buildings, combined with the recent occurrence of several damaging Oregon earthquakes, have raised concerns about the potential vulnerability of Oregon school buildings to earthquake damage. The building standards used to design schools and other buildings in Oregon and other parts of the country have changed over time as new information on regional earthquake hazards and the response of buildings to earthquake shaking has been developed. Oregon schools built before 1991 used earthquake design standards below those required in Oregon today. Schools built before about 1952 were unlikely to have used any earthquake design measures. Figure 2 shows changes in the Uniform Building Code (UBC) seismic zone map from 1946-1998 (see Technical Note). A survey of school buildings was needed to identify the level and the distribution of vulnerability among Oregon Communities.

The screening tool to collect data to be used in the vulnerability assessment was developed as a means to manage costs. The Oregon Department of Education estimated that it would take $1.2 million dollars to collect data on school buildings if one were to use standard building inventory techniques. A less expensive approach to identify areas of particular concern was desired. The screening tool developed relies on local

Figure 2. Diagrams showing history of Uniform Building Code zoning for the West Coast. Partially modified from International Conference of Building Officials (1997) and earlier issues of that series, except for 1998 diagram, which shows the western portion of the seismic zone map of Oregon, taken from Structural Engineering Committee (1998), as adopted by the Oregon Building Codes Division, Department of Consumer and Business Services. All eastern counties not shown here are included in Seismic Zone 2b (white); most of western Oregon is assigned to Seismic Zone 3 (light shade); and "all that land which lies westerly of Range 10 West of the Willamette Meridian from the north line of Coos County to the northerly line of Township 10 South (just south of Otter Rock), and all of Coos and Curry Counties" are included in Seismic Zone 4 (dark shade).

Technical Note

The Uniform Building Code (UBC) sets design standards adopted by most communities in the western United States. UBC earthquake design standards vary according to (1) the amount of ground shaking expected to occur in an area and (2) the distance of buildings to the fault or faults that may cause the shaking. The modern UBC defines five seismic zones based on these criteria, ranging from the highest level of ground shaking and nearest faults (Zone 4) to the lowest level (Zone 0). The Oregon State Building Code Agency assigned western Oregon to Seismic Zone 3 in 1991 as did the UBC in 1994.

district personnel to provide information to an initial survey questionnaire.

A "risk management" approach to the project was utilized to initially identify and analyze loss exposures. "Risk management" is defined herein to mean the process of making and implementing decisions that will minimize adverse effects of accidental and business losses on an organization. Terminology for risk managers differs depending upon the interested stakeholders, but generally for engineers, earth scientists, and other earthquake professionals, **hazard** refers to the earthquake itself and **risk** refers to the potential damages and losses caused by an earthquake and combines **hazard**, **vulnerability**, and **exposure**. **Vulnerability** refers to the degree of loss or damage to particular structures, or segments of society. **Exposure** refers to the items at risk (life, property, business interruption, etc.).

Risk management approach to mitigation and preparedness

Seismic mitigation by structural engineers most commonly means strengthening or otherwise improving the building's response to earthquakes in order to obtain a better building performance. A broader risk management perspective would define mitigation as those actions taken to implement risk-control measures that will be completed before the earthquake occurs. This definition includes traditional strengthening projects (retrofit), new design standards, maintenance procedures to improve building conditions, real-estate purchasing criteria, and occupancy criteria to reduce exposure, e.g., using older buildings for storage rather than for classroom use.

Emergency preparedness actions to develop an effective and rapid response capability to be implemented when an emergency occurs, may also help reduce the severity of losses by limiting the amount of additional damage and injury that may occur after the earthquake or during aftershocks.

Mitigation and preparedness are complementary loss-reduction strategies that are a part of any comprehensive risk control program.

A problem facing the school districts is that of funding costly building upgrades or replacement structures. Any program developed to reduce earthquake risk should identify those strategies that provide the "biggest bang for the buck".

STUDY METHODOLOGY

A seven-step process (Figure 3) is intended to screen out facilities of lower risk and direct funds to those in need. For individual buildings, a small number of buildings at an individual school site or for a small school district, step 2 is often undertaken to evaluate each building. With 1,200 public school buildings located throughout western Oregon, this task would be costly and time consuming. Thus, this project focused on the initial screening in step 1 (general questionnaire). The results of this step were to support the development of a methodology for school facilities personnel to use in preparing a seismic mitigation plan.

The Oregon Department of Education provided a directory of school facilities in Oregon. This information was used to develop a database of contact information for each school district located in seismic zone 3. Critical building information required to screen the vulnerability of school buildings and to develop an overall mitigation plan was not available from the state. Oregon school facility construction and funding is carried out at the school district level. Thus, the first task was to develop a survey questionnaire that could be filled out by facility personnel in each school district. The results of the survey would then be assembled in a database for prioritizing the school buildings.

Questionnaire

The general questionnaire developed was a nine-page document used to collect information on the vulnerability of the building structures, the exposure or value at risk (occupancy, use, historical value), and the opportunity for potential upgrades. The following items give a general indication of the types of information requested:

- General school district information (name, city, enrollment, etc.).
- General school information (name, address, contact person, enrollment, etc.).
- Building vulnerability/construction (construction date, type of structural system, number of stories, size/square footage, shape, deterioration, upgrades, etc.).
- Site (settlement, slopes, landslides, soil conditions, etc.).
- Building documents (availability of drawings or previous studies).
- Historic registry or value.
- Mitigation opportunities (schedule for demolition, repair, reroofing, etc.).
- Environmental risks (natural gas, asbestos, chemicals, etc.).

STEP 1 **Develop Seismic Mitigation Plan and Perform Initial Screening**	Agency facility managers complete their surveys Set program goals and objectives Define exemptions (filter exclusions) Perform initial screening Costs based on typical retrofit costs ($/sq. ft.) for building type Highest evaluated buildings of Step 1 are sent to Step 2
STEP 2 **General Structural Assessment**	Seismic Program Structural Engineer: ATC-21 approach plus Modify structural ranking Completes plan review of existing drawing Brief building field observation Evaluates buildings Costs based on typical costs for identified deficiencies Highest evaluated Step 2 buildings are sent to Step 3
STEP 3 **Detailed Structural Evaluation**	Population Consultant Structural Engineer: Prepares structural analysis of selected buildings Prepares evaluation report Highest Step 3 buildings sent to Step 4 Costs based on engineer's analysis and identified deficiencies
STEP 4 **Cost Analysis (Cost)**	Consultant Structural Engineer prepares Schemes and Structural Estimate Benefit-cost ratio (BCR) prepared for: Part 1: Structural retrofit only (Structural BCR) Part 2: Structural retrofit plus (Total BCR) Fire and life safety Asbestos and other hazards Access All of Step 4 buildings are sent to Step 5
STEP 5 **Recommendation (Report)**	Final report Recommendations made for projects to be included in budget
FOLLOWING BUDGET APPROVAL:	
STEP 6 **Detailed Design**	
STEP 7 **Implementation**	

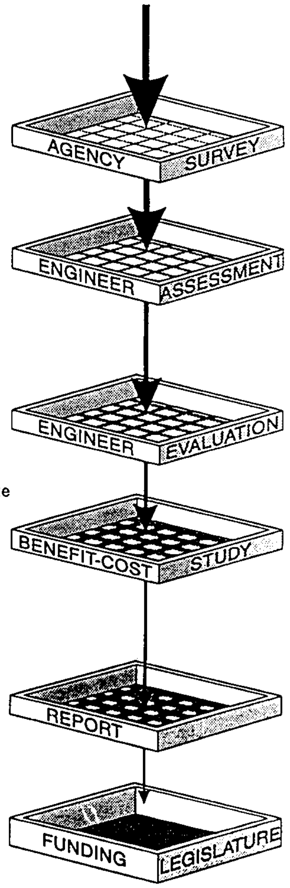

Figure 3. Summary description of seven-step procedure to assess school earthquake vulnerability and act on it.

- Past earthquake damage.
- Occupancy (occupancy, hours, etc.).
- Building function (school use, nonstudent use, plans for community shelter).
- Relocation (alternate sites).
- Comments on completing the survey.

The questionnaire was sent out to 173 school districts in western Oregon. Responses were received and logged for 93 districts (55-percent response). Data entry using Microsoft Access and preliminary data analysis was completed for approximately 20 percent of the districts surveyed. Late responses and the termination of funding for the project prevented the input and analysis of the remaining data.

Screening/ranking methodology

Initial results for the completed questionnaires were screened using a methodology and ranking system previously developed for the City of Seattle buildings. The informal prioritization method shown in Figure 4 utilizes a weighted point-ranking system based on the structural risk (exposure, vulnerability, and hazards), function rank, opportunity, and historic value.

PRELIMINARY RESULTS

Examples of the results are displayed graphically in Figures 5 and 6. As noted above, data entry was not completed for all of the responses received, data were not verified, and the informal prioritization method was not modified to account for items specific to the project such as benchmark years of local construction. However, preliminary results of the data can indicate some interesting trends.

THE NEXT STEP AND BEYOND:

In order to complete the Step 1 initial screening and data collection, which will assist in developing the mitigation plan, several tasks should be completed as follows:

1. Complete Oregon school vulnerability study.

- Complete data entry (late responses), review building

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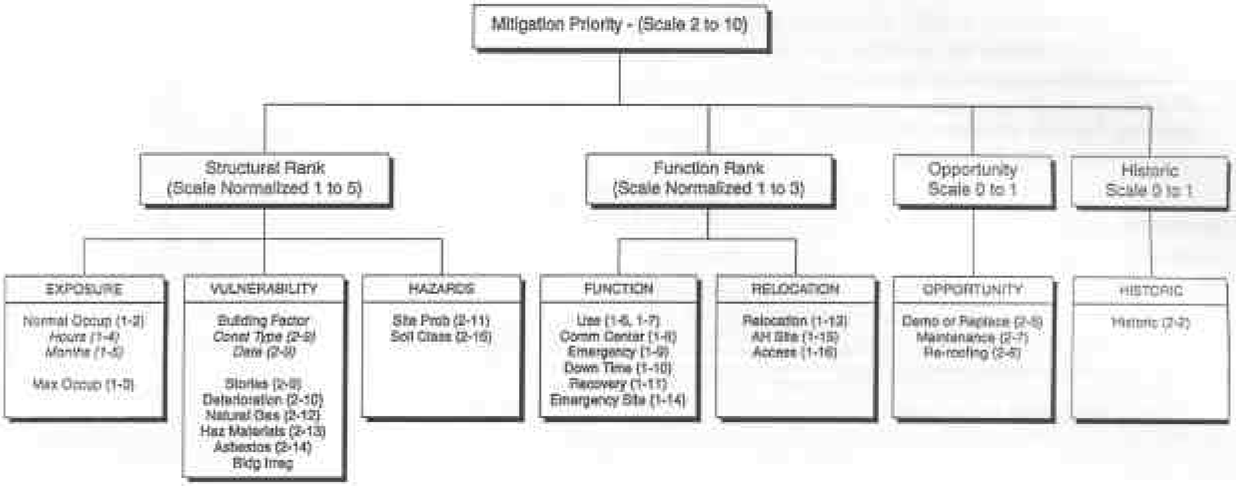

Figure 4. Schematic representation of Informal Prioritization Method developed for buildings of the City of Seattle

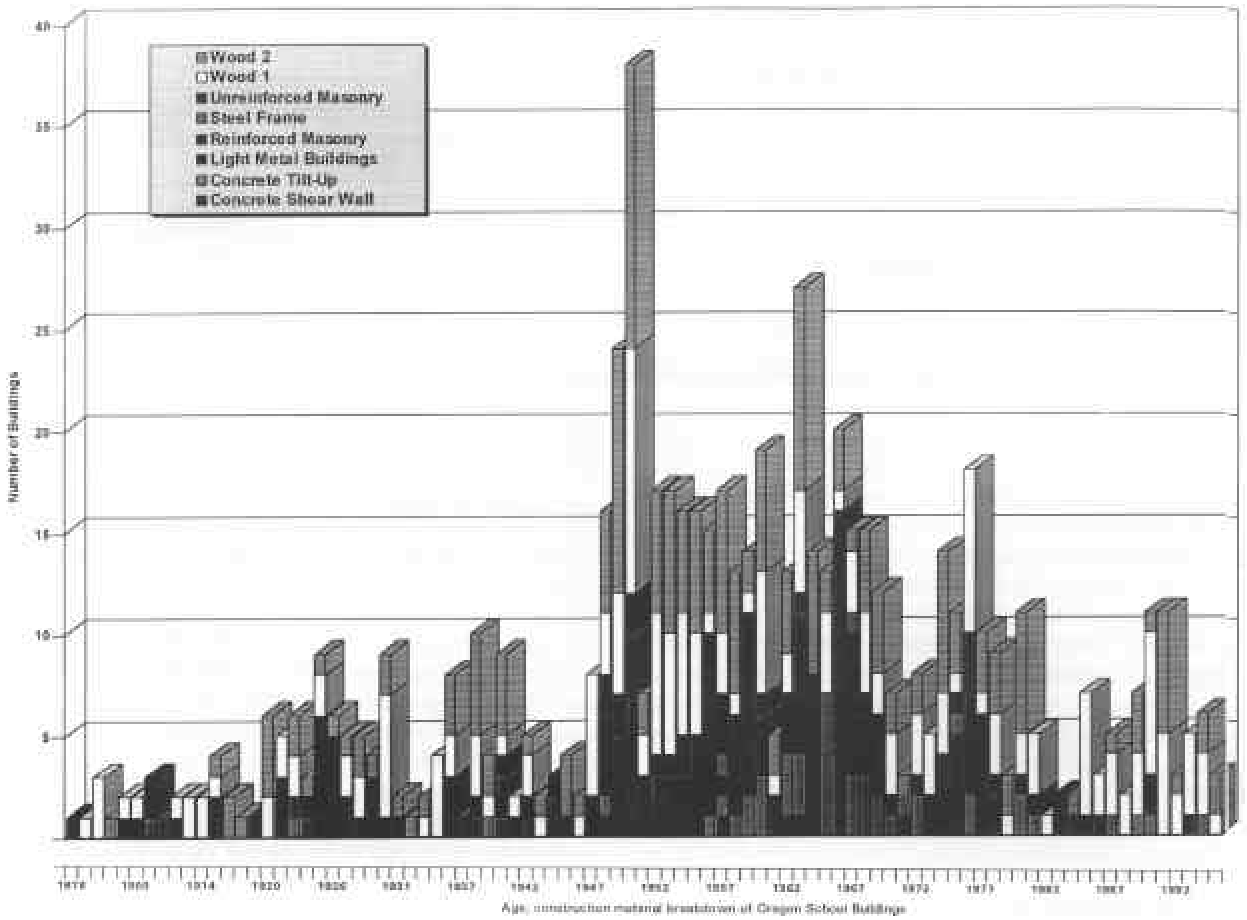

Figure 5. Number of surveyed Oregon schools by age, also indicating construction type.

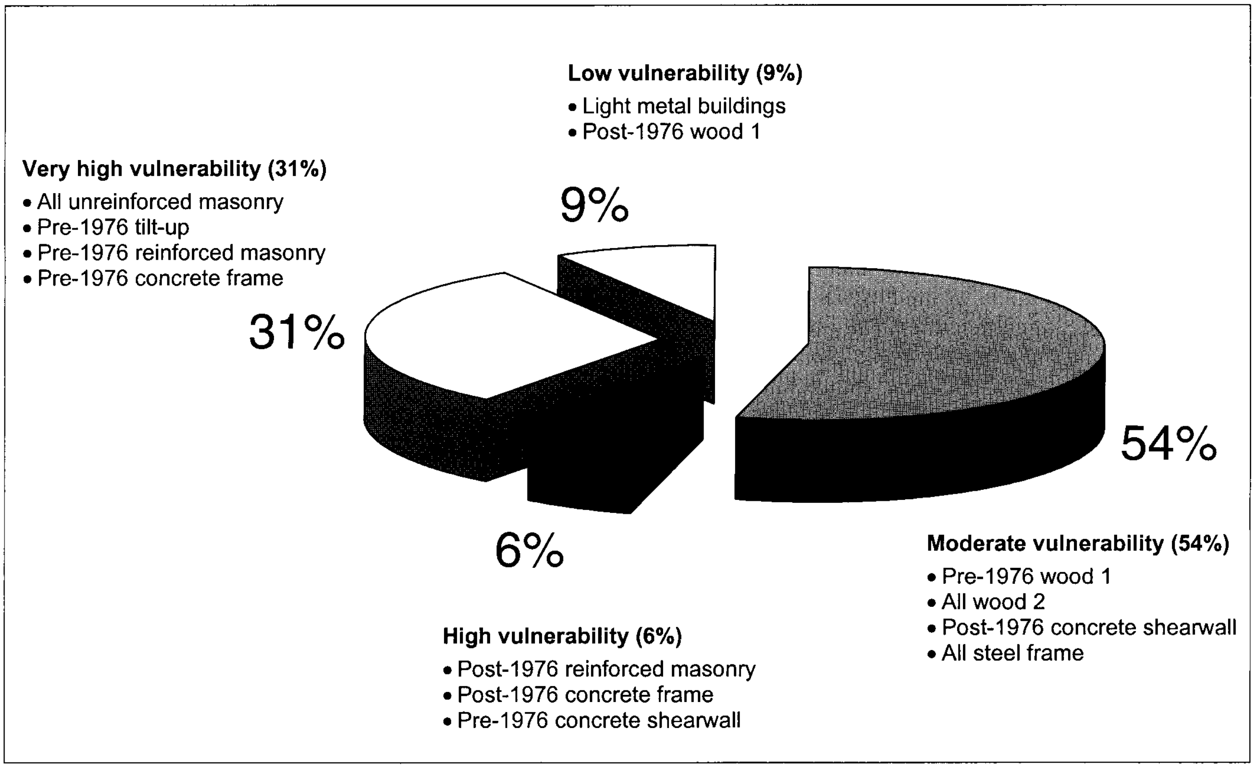

Figure 6. Distribution of surveyed schools according to vulnerability category: very high, high, moderate, and low.

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surveys, confirm missing/confusing data, modify responses as needed (e.g., construction dates of 1996 and unreinforced masonry are not feasible).

- Establish weighted functions to sort collected data into mitigation priorities, including benchmark years showing dates when critical earthquake design requirements were adopted, buildings to be exempted from the program, etc.
- Complete database design.
- Complete Oregon school vulnerability study by sorting weighted database by selected mitigation parameters. Determine vulnerability groupings by schools and districts.
- Report findings.

2. Prepare risk-based mitigation methodology.

- Conduct field evaluations of four to five representative school districts to verify vulnerability study.
- Revise database and mitigation weighting functions as appropriate.
- Prepare mitigation planning methodology based on the results, including criteria, district qualifications and ranking procedures.

3. Develop and deliver mitigation planning workshops.

- Topics to include overall vulnerability of the Oregon schools, approaches for seismic screening and evaluation of school buildings, cost estimation, integrated school planning models, criteria for State mitigation program.

SUMMARY

A general questionnaire was developed and completed to assist in the identification of earthquake exposures and the associated risk to western Oregon schools. Returned data were not complete nor were they standardized. However, several interesting trends can be concluded. In order to reduce the potential risk to the Oregon school system, a combination of mitigation and planning should be performed. Step 1 information can assist in prioritizing funding for both the mitigation and planning process. Proper evaluation of the needs of public schools in Oregon with respect to seismic design will require additional professional survey work with standardized procedures.

REFERENCES

International Conference of Building Officials, 1997, 1997 Uniform building code, v. 2, Structural engineering design provisions: International Conference of Building Officials, Figure 16–2, p. 2–37.

Structural Engineering Committee, 1998, Seismic zonation for the Oregon coast.: Final report submitted to the Building Codes Structures Board, February 12, 1998 (for Oregon Building Codes Division), p. 9. ☐

Seismic risk reduction efforts in Tillamook honored by WSSPC

Tillamook County General Hospital (photo below) has received an "Award in Excellence" for new technology from the Western States Seismic Policy Council (WSSPC).

With the award, the multi-state Council recognized the successful efforts of the County to improve the structural safety of the hospital from the destructive effects of earthquakes. The goal was to strengthen the facility so that it would allow immediate occupancy after a 500-year return interval earthquake.

In the course of renovating and expanding the hospital facilities, fluid viscous dampers were installed in "dynamic" braces (example in photo on right) that will dissipate shaking energy. The improved elastic design exceeds the required standards of Seismic Zone 3. It actually satisfies Seismic Zone 4 standards, which are required only in areas along the southern Oregon coast.

The fluid damper technology itself is a century old. However, its use in Tillamook is the first time in history that it is applied to a "fixed-base" hospital, i.e., a hospital with a base not already specially designed to ride out earthquakes.

The use of this approach made construction of additional shear walls unnecessary and kept construction-related disturbance of the hospital to a minimum.

For a description of the project, see Craig Keller, 1998, "When in doubt, damp it out": Connections (a publication of the Structural Engineers Association of Oregon), April 1998, p. 5–6. ☐