The Klamath Falls, Oregon Earthquake of September 20, 1993

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INTRODUCTION

At 8:29 p.m. local time on Monday, September 20, 1993, a strong earthquake was felt in much of south central Oregon and as far away as Portland. The Klamath Falls earthquake registered 5.7 M_s and was estimated to be at a depth of 5 km. This was followed by a 5.5 M_s event at 10:45 that same evening.

Two deaths were attributed to the earthquake. One was due to a rock slide onto highway 97 and the other to heart failure of an 82-year-old woman.

The epicenter of the first major event was estimated to be 25 km (15 miles) west-north-west of Klamath Falls. One foreshock and seven aftershocks of magnitude 4 or greater were measured within three days of the main event. The nearest strong ground motion recorders were located approximately 50 miles away. Peak ground accelerations in the epicentral vicinity are therefore unknown.

Seismic activity in the Klamath Falls area is related to volcanic activity. Many minor surface fractures traverse a region within a thirty-mile radius of Klamath Falls (Figure 1). Numerous hot springs are located in the area. The City operates a geothermal system supplying hot water for building heating systems.

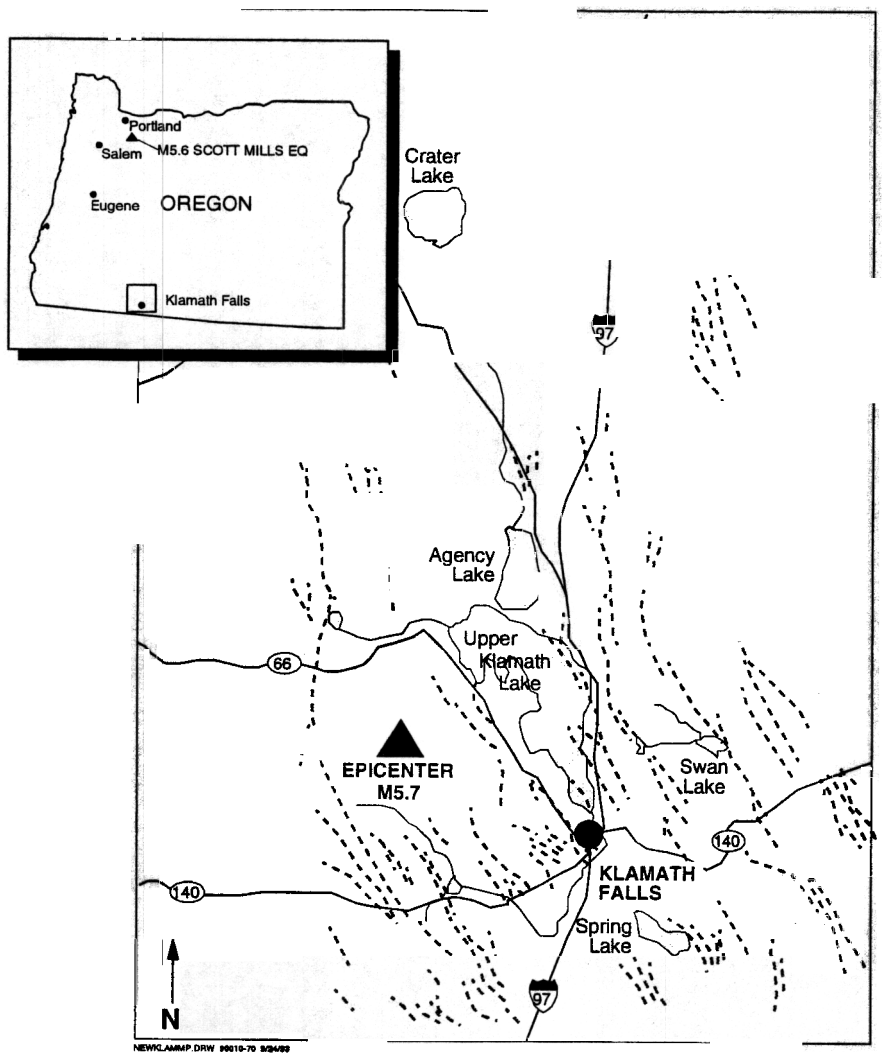

Figure 1 - The epicenter of the M5.7 was about 15 miles west-north-west of Klamath Falls. Minor surface fractures are numerous in the area. The inset shows the location of March 25 1993 Scotts Mills earthquake.

This seismic/volcanic activity has resulted in less than half a dozen seismic events of Modified Mercalli Intensity (MMI) IV or greater over the last hundred years in the Klamath Falls region. The September 20 event, estimated to have had an intensity of VI to VII in Klamath Falls, is one of the largest recorded events occurring in the state of Oregon. This is the second large earthquake in the state this year. The March 25, 1993, Scotts Mills Earthquake in northern Oregon had a magnitude of 5.6 M_s.

The 1985 *Uniform Building Code* (UBC) specified much of the state of Oregon, including the areas near Klamath Falls, to be in seismic Zone 1. The rest of Oregon was Zone 2. The 1991 UBC specified all of Oregon to be Zone 2B. In 1993, the seismic zone for the western portion of Oregon, which includes Klamath Falls, was upgraded to Zone 3 in recognition of the potential for higher seismic activity than had previously been anticipated.

The geology of the area consists of unconsolidated to semiconsolidated lacustrine clay, silt, sand, and gravel; mudflow and fluvial deposits and discontinuous layers of peat occur in places (Geologic Map of Oregon, Walker and McCleod, 1991).

With a present population of 17,000, Klamath Falls is the hub of the timber industries in south central Oregon. Outside of Klamath Falls the region is sparsely populated.

BUILDINGS

Building damage in the Klamath Falls urban area was minor to moderate, with the greatest proportion of damage occurring to the parapets of older, unreinforced masonry (URM) buildings. Based on preliminary information, greater damage appears to have been sustained by those buildings which are situated on unconsolidated soil deposits. Nearby URM structures of similar configuration founded directly on basalt or siltstone suffered little or no damage.

The original downtown section of Klamath Falls was constructed in the early 1900s, and is comprised mainly of unreinforced brick buildings along the parallel streets of East Main and Klamath Avenue. The commercial buildings in the downtown area are typically one to three stories in height, the tallest being six stories.

Figure 2 - The One Stop Auto Building lost portions of its walls in addition to its parapet due to inadequate attachment of the walls to the roof. Apparently, no parapet bracing had been done in Klamath Falls before the earthquake.

At least seventeen buildings in the downtown area sustained structural damage. No building collapses were reported, although some structures were classified as unsafe and may be demolished. A total of 93 residences had some damage according to initial Red Cross reports, approximately one-third being major and two-thirds minor. Damage included toppling of chimneys and houses shifting on their foundations.

In the URM buildings, the majority of the damage was confined to the parapets. There appeared to have been no attempts to brace the parapets of these buildings prior to the earthquake. Inadequate attachment of the walls to the roofs also caused damage: sections of walls beneath the roof level fell with the parapets. The most graphic examples of this occurred at the One Stop Auto Building (Figure 2) and the Stevens Building (Figure 3). At the latter structure, much of the parapet fell on an unoccupied automobile parked on the street below. The Stevens Building also suffered large shear/flexural cracks in the storefront brick piers.

Major structural damage occurred to the three-story URM Arcade Hotel: the wall moved away from the unattached roof and floor framing. The structure has been classified unsafe and may be demolished. The URM McKeen Building has also been closed due to wall movement away from the floor and roof framing.

Evidence of pounding was found between the Pelican Building and an adjacent structure, both on Main Street. There was no separation between these two masonry structures. The Pelican Building is three stories tall; the adjacent structure is one story.

The largest building with significant damage was the three-story Klamath County Courthouse. The original portion of this building was constructed in 1911 with a major addition built in the 1960s. The

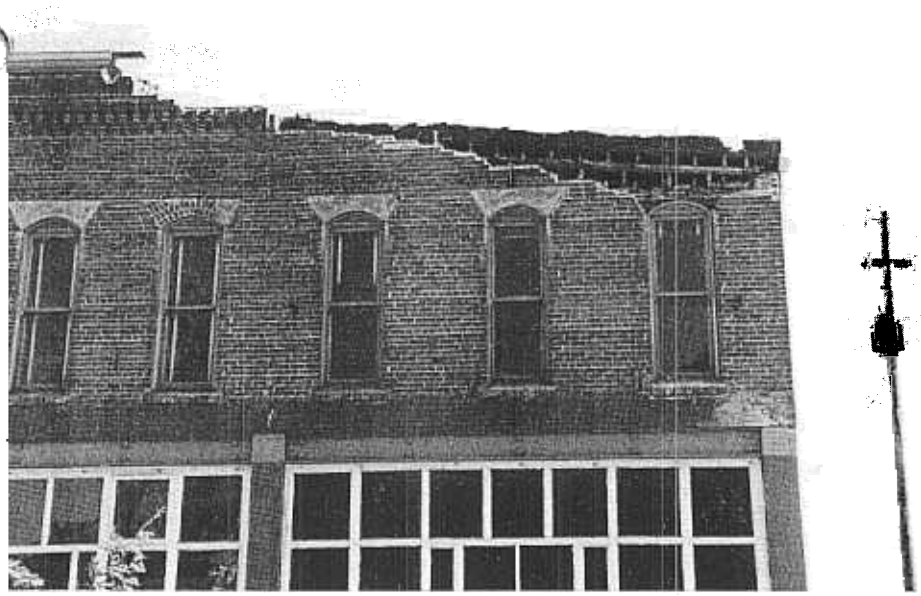

Figure 3 - The Stevens Building lost part of its parapet and wall, and suffered large shear/flexural cracks in the storefront brick piers.

1911 portion, approximately 30 by 37 meters (100 by 120 feet) in plan, was constructed with brick perimeter walls, interior concrete columns, and hollow clay tile interior partitions. The 1960s addition, approximately 18 by 37 meters (60 by 120 feet) in plan, was constructed with steel columns with a metal and glass curtain wall. Brick placed in stacked bond construction was used at the southeast end of the addition.

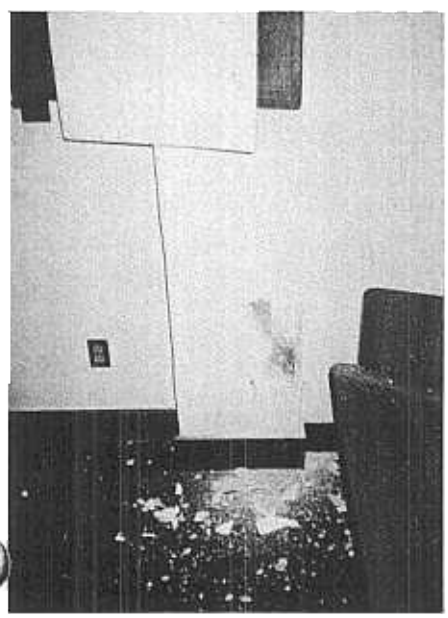

Figure 4 - Concrete columns in the County Courthouse were damaged.

Both portions of the building experienced significant damage. The damage to the original building included significant cracking of the plaster covering of the perimeter walls, cracking of the hollow clay tile partition walls, and some cracking of concrete columns (Figure 4). Extensive nonstructural damage occurred, including loosened and fallen terra-cotta coving and marble wainscoting, and fallen suspended acoustical ceilings.

No positive structural connection attached the two portions of the building. The 1960s addition, as a result, had essentially no lateral system at the portion of the addition adjacent to the original structure. Large displacements of the addition therefore occurred as well as pounding between the two portions of the building. The large displacements caused significant cracking in the brick wall at the end opposite the original structure, damage to a bridge structure connecting the addition to an adjacent abandoned jail, and failure of the structural attachment of several of the steel staircases (Figure 5).

Several peculiar items are also noteworthy. The Baldwin Hotel Museum, a URM structure built in 1907, was undamaged during the earthquake. This structure is only several hundred yards from the courthouse and has had steel mesh draped over the deteriorated storefront for a number of years to guard passers-by from falling masonry. No masonry appears to have fallen during the earthquake or aftershocks. The building also has a large expanse of stained glass in the storefront which remained uncracked. The structure is founded on basalt.

The Modoc Energy Products complex, a chip, pellet, and lumber mill adjacent to the courthouse, suffered no damage except for a partial parapet collapse at a URM structure. The complex contains a variety of structures from rigid timber frame buildings and bowstring truss structures to chip lines and elevated pellet bins.

One of the largest structures in the area, a retail store about two miles from the downtown area, is a relatively new single-story, reinforced concrete tilt-up building. No visible damage was observed, even in the complex spandrel panel arrangement at the entries.

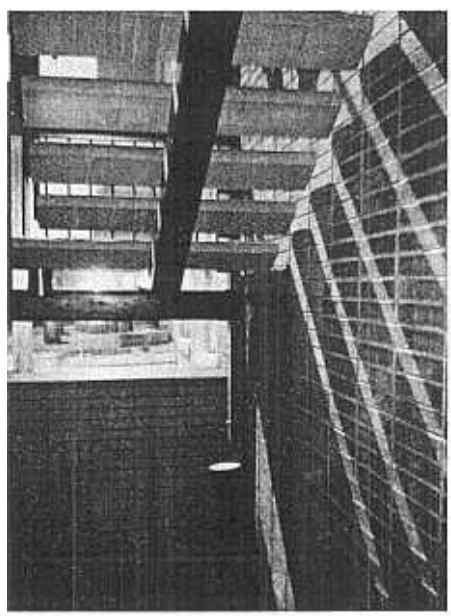

Figure 5 - Steel stair supports were also damaged at the courthouse.

BRIDGES

The Sixth Street Viaduct, near the downtown area, is a railroad bridge built in the 1930s or 1940s. It is a four-span structure consisting of reinforced concrete approaches on each end with two steel center spans. The three support piers are reinforced concrete. Slight damage in the form of spalled concrete occurred at the top of the first interior pier where both concrete and steel girders are supported. Apparently as the steel girder separated from the concrete girder, the concrete spalled at the area directly beneath the steel girder bridge bearing. This condition, similar to damage observed in past seismic events, was not serious and did not close the viaduct.

LIFELINES

Electrical

Following the earthquake, periodic power outages occurred. The outages were attributed by Pacific Power and Light representatives to swinging low voltage power lines impacting adjacent lines, resulting in shorts and subsequent trips of breakers. No outages were attributed to damage to substations or electrical equipment. Observations of typical substations revealed that main transformers were typically not anchored. However, no shifting of equipment was observed.

Gas

No interruption of gas service was experienced. One breakage in a small service line was reported at an abandoned residence. The damage was believed to be due to displacement of the residential structure during the earthquake.

Water

At least three separate breaks occurred in 6-inch water mains in the downtown area due to the severe ground shaking. The breaks were repaired within several hours of the earthquake. These lines, according to city water works representatives, were all cast iron, as is most of the water distribution system in the city center area.

Geothermal

No damage was observed to the geothermal system. The main downtown loop, however, was out of service and not pressurized when the earthquake occurred.

Waste Water

No damage to the waste water distribution system was reported. One concrete tank at the waste water treatment plant was observed to have had some slight leakage at an existing crack. This crack had been repaired prior to the earthquake. The ground shaking apparently caused minor opening of the existing crack.

Telephone

Although no direct damage to telephone switching equipment was reported, telephone service into and out of Klamath Falls was greatly limited due to the inability of the system to handle the volume of calls generated by the earthquake. This huge demand on the phone system is a common occurrence following earthquakes.

Fire

According to the Klamath Falls Fire Department, no fires were caused by the earthquake.

Transportation

Highway 97 is the primary north-south corridor between north central California and central Oregon. Following the Monday night earthquake the highway was closed for less than one day. Rock slides spilled onto highway 97 north of Klamath Falls resulting in the death of one man.

CONCLUSION

The nature and extent of damage caused by the September 20, 1993, Klamath Falls earthquake conclusively reveals the high degree of hazard that exists in unreinforced masonry structures, especially those where inadequate parapet bracing and insufficient anchorage of the roof and floors to the walls exists. Since this earthquake and its aftershocks can be considered minor to moderate, the degree of seismic risk of URM buildings is apparent. The role of soil-related effects in aggravating the ground motions was also illustrated by the earthquake.

The extensive damage to the County Courthouse has resulted in the long term evacuation of the building. Had the earthquake occurred during working hours, many more deaths and injuries may have resulted.

The area lifelines, with the exception of closure of highway 97 due to rock slides, performed relatively well. Minor power outages occurred as well as breaks in several water mains.

The September 20, 1993, M_S Klamath Falls and March 25, 1993, M_S 5.6 Scotts Mills events are two of the largest seismic events to have occurred in the state of Oregon. Both events caused similar damage to structures and lifelines. These earthquakes reinforce the fact that a significant portion of the state is prone to damaging earthquakes. Due to limited recent seismic activity, little attention has been given to seismic hazards in the region. While seismic awareness is high, actions should be taken to reduce life safety risks in hazardous buildings and increase the reliability of area lifelines.