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Building Damage from the 2008 Wells, Nevada Earthquake

by

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ABSTRACT

Wells, Nevada had about 80 commercial and government buildings that were subjected to shaking from the 2008 Wells earthquake, a magnitude 6 event within 9 km of town. Over half of the nonresidential buildings were damaged (42+), 17 of these had major damage. Modern construction performed well, although all buildings in Wells had some cracks from being rocked back-and-forth strongly.

The worst damage was to buildings in the historical district of Wells, many of which were unoccupied and were poorly maintained. One building collapsed and three buildings were partially collapsed by the earthquake; these were two-story buildings, except in one case, where the collapse may have been caused by debris falling from a two-story building. Fifteen buildings lost sections of parapets and/or walls. Most of the severely damaged buildings were unreinforced masonry bearing-wall buildings (URMs), but there were also damaged wood-frame buildings with unreinforced brick veneers and walls. Twelve of the 16 unreinforced brick buildings in the Wells historical district had major damage. Several buildings in other parts of Wells also had significant damage, most notably the City Hall, City Shop and high school buildings.

A particularly damaging component of unreinforced masonry walls was the crowning, concrete bond beam on the top of most URM walls. In many cases, the upper parts of these walls were only two wythes wide (two bricks wide). When these crowning bond beams destabilized and fell, they came down in larger pieces than the bricks of the wall. In one case where a crowning bond beam was lightly reinforced with rebar and fell from a two-story height, it smashed down onto a balcony and crushed a car, illustrating the potential destructive force of these components. The tops of URM walls, crowning bond beams, and parapets should be anchored to structures.

Several partially reinforced and unreinforced concrete block masonry buildings had broken and separated blocks in the areas of connections with beams and joists and in the corners of the buildings, and had cracks trending diagonally through buildings, with most cracks stair-stepping in the mortar seams between the blocks. In at least one case, some pre-existing construction defects may have promoted failure: a damaged block wall section that should have been filled with concrete below a major beam to form a column was instead only partially filled and could therefore not support the earthquake loads from the beam. As a result, the wall began to break up.

Engineering factors that likely contributed to building damage from the 2008 Wells earthquake include the following:

- seismically weak building types such as unreinforced masonry buildings.
- poor-quality building materials such as old mortar, unfired bricks, and rubble infill.
- lack of seismic detailing in buildings such as unanchored parapets; ceiling and walls not tied together; and brick veneers inadequately tied to the walls.
- construction defects such as poor masonry (rubble infill, unfired bricks), lack of cross-tie bricks, missing mortar between bricks, and incompletely filled block columns.
- second-story effects such as greater deflection and possible longer period excitation.
- specific location such as being next to and damaged by a collapsing building.
- local site conditions such as soils classified as International Building Code NEHRP Site Class D (Wells Refraction Microtremor measured V_s30 shear-wave velocities from 280 to 358 m/s).

In order to evaluate the advice that is often given to not run out of URM buildings during an earthquake, I compared the number of debris-ridden versus clear exits from damaged URM buildings in the historical district to the probable survivability inside of these buildings. There were 16 damaged URM buildings with a total of 36 exits among them. Out of the 36 exits from these buildings, 21 of them (58%) had bricks thrown down in front of them (in two cases the bricks had been caught by a balcony and a roof, thus protecting the exit). Of the 16 damaged URM buildings that were evaluated, only one, the San Marin Hotel, had significant interior damage with minimal survivable space (this building totally collapsed and shed debris down across its exits). Thus, during the 2008 Wells earthquake, it would have been safer for occupants to have stayed inside the damaged URM buildings than to have exited them, where they would likely have been hit by falling debris from heavy collapsing brick parapets in many cases. One partially collapsed building was occupied by seven people, who stayed inside during the earthquake and survived uninjured. These observations support the advice that the safest course of action during an earthquake is not to run into or out of an unreinforced masonry building. The one building that did collapse, however, reminds us that URM buildings ultimately need to be rehabilitated for seismic shaking.

The earthquake damage to 18 buildings is briefly discussed and illustrated in appendix 1 at the end of this paper.

Nevada is earthquake country and Nevada communities commonly have between a few and many unreinforced masonry buildings. Some ideas for seismically rehabilitating these buildings and making them safer can be found at FEMA (2009) and at the following link: http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/02-02-EARTHQUAKE/1-BUILDINGS/E~-Mitigation-Measures.htm.

INTRODUCTION

Wells is a small city located in northeastern Nevada (figure 1) with about 80 commercial and government buildings, of which only a dozen or so are two stories high, the rest being single-story structures. Construction types include wood frame, steel frame, reinforced masonry, and unreinforced masonry (URM), and several buildings have multiple types of construction (e.g., unreinforced brick front half with a wood-framed rear). The construction periods of these buildings range from the late 1800s through the 1900s. Some have served multiple purposes and businesses for over a century whereas others are in their first episode of use. The historical district of Wells (figure 2), was laid out along the railroad tracks; nearby water wells were used to fill water tanks on passing steam engines.

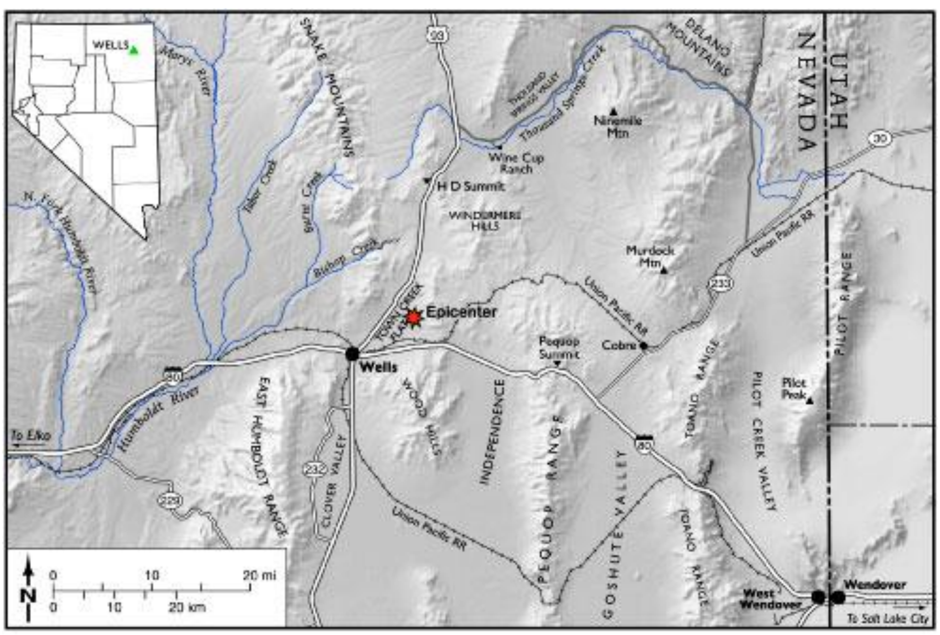


Figure 1. Location of Wells, Nevada and the epicenter of the 2008 earthquake.

Figure 2. Front Street of the Wells historical district prior to the earthquake. Only two of the buildings in this block were being used and none were occupied during the event. *Photograph by Jack Hursh*.

The most severe damage from the earthquake was to the weaker older URM buildings, most of which were built in the early 1900s. These buildings have experienced many decades worth of large snow loads, high wind loads, varying occupancy loads, and large seasonal temperature fluxes, all of which have aged them. Some have also been exposed to fires. The mortar used between the bricks is old, has weakened with age, and is generally considered inferior to that used today. Subsequent repairs to the walls are commonly partial (usually only done near the top of the wall) and create areas with new stronger bonds that can behave as relatively coherent masses. In addition, the financial stability of the buildings' occupants has varied through time (e.g., Great Depression, highway construction boom, freeway bypass decline), which has resulted in varying levels of building maintenance over time as well.

Earthquake damage has exposed poor construction quality and materials in several cases. Some of the buildings appear to have been built as quickly as possible with whatever bricks and rocks were available. In some cases, the cross-laid courses were absent and columns of bricks were simply stacked next to one another (this was most commonly done near the tops of walls). These buildings predate building codes and there was no consideration of using seismically resistant construction methods or materials in them.

Despite these noted deficiencies, there were elements that likely added some lateral resistance to the buildings in the historical district. One remarkable aspect is the strength of the roof systems in these buildings. They are commonly truss systems designed to withstand large snow loads. Another aspect is the buttressed nature of many of the buildings resulting from being adjacent to one another or from having common walls. Adjacent buildings appeared to support each other. Although roof and ceiling joists were simply set into slots and not attached to the walls, this buttressing may have helped support the stresses coming through the connections and helped prevent the joists from coming out of these slots. Another note is that prior to the earthquake, several of the weaker buildings had been braced with temporary wooden floor-to-ceiling columns to strengthen the roof and floor support and other members that had weakened with time; in no cases did the roof or floor fail when braced this way.

Wells' more modern buildings, in contrast to the older ones, are built with better materials and with some seismic resistance. Currently, the 1997 version of the UBC is enforced by the City of Wells; this version includes improvements made to the code following the 1971 San Fernando earthquake, the 1989 Loma Prieta (Bay Area or World Series) earthquake, and the 1994 Northridge California earthquake, so there are several improved seismic provisions incorporated into it.

The structural damage suffered by buildings in Wells due to the 2008 earthquake can be grouped into several categories: collapse and partial collapse of buildings; parapet and wall damage; unreinforced brick veneer damage; and additional damage to pre-existing damage. Additionally, there was widespread nonstructural damage to the buildings (e.g., broken chimneys, broken windows, cracked walls).

With the exception of one mobile home, shifting of buildings off their foundations or jacks was not a common occurrence from this earthquake. Manufactured buildings and homes were commonly shifted on their jacks, but they tended to stay on. It is unclear to what extent buildings were anchored to their foundations, but when resetting the shifted buildings, they were commonly strapped or anchored to some degree to help them stay on in the future.

This is a report of reconnaissance observations made mostly on the outside of buildings, but in some cases, additional observations were made of their interiors. It does not constitute a detailed analysis of each building's condition, but focuses on major damage to buildings and comments on their general condition. Unreinforced masonry construction and the damaged buildings in the historical district were the primary focus, and the investigation did not comprehensively observe all the buildings in town because of time limitations. Minimal attention was given to undamaged and modern buildings. The paper is organized into a discussion of the types of damage that occurred and then by the different construction types. Some detailed notes on 18 individual buildings are in appendix 1 at the end of this paper.

The intent of this paper is to document significant nonresidential building damage resulting from the Wells earthquake. Damage to residential housing is covered in a separate paper in this volume (dePolo, this volume). I am a research scientist and not an engineer, which creates some limitations and some advantages to these observations.

Earthquakes are the ultimate shaking laboratory (or "shake table"), so such documentation is important. The kinds of buildings and earthquake threats that are present in Wells are common to many western communities. These observations may therefore be useful in modeling a possible damage profile for these communities should an earthquake occur. Some ideas for preventive seismic rehabilitation of buildings, and in particular for unreinforced masonry buildings, can be found in FEMA (2009) and at the following Internet link: http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/02-02-EARTHQUAKE/1-BUILDINGS/E~-Mitigation-Measures.htm

THE 2008 WELLS EARTHQUAKE

The Wells earthquake occurred on February 21 at 6:16 a.m. PST (14:16:02.62 UTC). The earthquake had normal dip-slip motion, a moment magnitude of M_w 6.0, and a moment release of 1.3 x 10^{18} N-m. The event began at a hypocenter 9 km to the north of town, and ruptured in the subsurface to within 1 to 2 km of Wells. The earthquake does not appear to have ruptured the surface and occurred on a previously unmapped fault, although parts of the general fault zone it belongs to were mapped 30 km to the north. The surface projection of the earthquake fault is within the Snake Mountains (Smith and others, this volume). There is not an obvious Quaternary fault in this position, and although there are some equivocal geomorphic features in the area, the amount of potential Quaternary offset appears to be minor, if any (Ramelli and dePolo, this volume). Thus, the earthquake is a background earthquake, a kind that can occur anywhere in Nevada or in the Basin and Range Province (c.f., dePolo, 1994). The occurrence rate of background earthquakes is generally determined by analyzing historical earthquakes. Estimates of the chances of a magnitude 6 or greater earthquake within 50 km of the Wells area occurring over the next 50 years were calcultated to be about 10% to 12% (http://geohazards.usgs.gov/eqprob/2009/index.php). This is one of the lowest chances of this size event happening in Nevada, yet the damaging Wells earthquake occurred, reinforcing the oft-repeated warning that damaging background earthquakes can, and do, occur anywhere at any time in tectonically active Nevada.

The Wells earthquake occurred on a N40°E-striking fault, with a 55°-southeastward dip. The earthquake is thought to have had a relatively high stress drop for a normal fault, 72 to 89 bars, and had a bilateral rupture nature that caused it to occur very quickly (Smith and others, this volume; Mendoza and Hartzell, this volume). The earthquake occurred directly under a sedimentary basin that forms Town Creek Flat, the valley in which Wells lies. This sedimentary basin, modeled principally on gravity measurements, is a maximum of 1.8 km deep near the epicenter and shallows towards Wells, where it is about 200 to 500 m deep (Ponce and others, this volume). The basin and its configuration likely contributed to enhancing strong ground motion and lengthening shaking duration.

There were no recordings of the strong ground motion from the mainshock in Wells. Modified Mercalli Intensities were up to VIII in the historical district, VII for much of central Wells, and VI in the southern part of Wells, progressing to a lower intensity away from the earthquake. Durations of earthquake shaking reported in Wells range from 20 to 40 seconds. Peterson and others (this volume) found that regional seismic recordings of the mainshock were generally compatible with ground motion prediction equations in the National Seismic Hazard Maps (NSHM), although they were below the predicted curves at distances of about 200 km and greater. Near-source ground motions of Wells aftershocks were recorded on a local portable seismic array. One of these aftershocks, a M_w=4.3, was recorded at the Wells fire station, which is within 100 m of the area of highest damage levels reported from the mainshock (Modified Mercalli Intensity VIII); the fire station is on a soil site with approximately 297 m/s V_s30 shear wave velocity (O'Donnell and others, this volume) and was about 13 km away from the aftershock's epicenter. Petersen and others (this volume) report that ground accelerations from this aftershock at this site "exceeded 0.2 g and experienced sustained accelerations above 0.1 g for about

5 seconds," which is close to the peak ground acceleration predicted for Site Class D by the NSHM, 0.2 to 0.3 g. The mainshock of the Wells earthquake caused Intensity VIII damage near this site, whereas this aftershock only caused a few bricks to fall from the upper parts of damaged buildings (I was standing about 50 m south-southwest of the station when the earthquake occurred), thus the mainshock likely had stronger and longer ground motion. There were some high-amplitude waves in the 3-5 Hz frequency range relative to a Brune spectrum model for the east component of the recording from the aftershock, which Petersen and others consider possible evidence of site effects in the ground motion.

Six Refraction Microtremor measurements were made in Wells to get a preliminary view of the V_s30 shear-wave velocity of local deposits (O'Donnell and others, this volume). O'Donnell and others found that shear-wave velocities in the historical district were about 297 to 303 m/s (973 to 994 ft/s), and in central Wells were 300 to 358 m/s (983 to 1,174 ft/s); all locations have velocities that put them in International Building Code Soils Site Classification D. There were also some potential shallow velocity reversals which also may have influenced ground motion.

DAMAGE TO BUILDINGS

The earthquake damage in Wells ranged from the complete collapse of a structure to hidden and hard-to-discover cracking. Much of the damage is typical of what would be expected from an earthquake, with the worst damage occurring to older, unreinforced masonry buildings. Almost half of the nonresidential buildings in Wells had some earthquake damage, costing at least thousands of dollars each to repair.

These observations were constrained by time, so only the commercial and government unreinforced masonry buildings and the damaged buildings in the historical district were the focus. Forty-two damaged buildings were noted (table 1). Brief descriptions and pictures of the damage to 18 buildings are included in appendix 1 located at the end of this paper. The locations of 35 of the damaged buildings in Wells are shown on two maps, one of the City of Wells and one of the historical district. Historical dates of buildings are from the Wells "Old Town Front Street Walking Tour," produced by The Wells Society for Preservation of Wells Heritage. Two severely damaged buildings, the high school gymnasium and auditorium, are discussed in a separate paper in this volume (Trabert, this volume).

Table 1. Earthquake-Damaged Buildings that were Examined*

Buildings with Structural Damage

Total or Partial Collapse

Location	Building	Building type	Damage Level	Damage
Figure 4, #7	San Marin Hotel	URM, brick	total	total collapse of walls, floors, and roof
Figure 4, #4	Nevada Hotel	URM, brick	severe	roof dislodged, buckled, fell, and rotated; major upper wall failures
Figure 4, #3	Mint Saloon	wood	severe	roof and wall collapsed from falling bricks from adjacent building
Figure 4, #16	El Rancho Hotel	URM/steel/wood/brick	severe	roof dislodged, upper wall failures

Broken Walls, Beams, Connections

Location	Building	Building type	Damage Level	Damage
Not Shown	4-Way building	CMU?	mod.	interior bearing wall damage
Figure 4, #13	Bullshead Bar	wood/URM, brick ven.	heavy	outer veneer failure, brick wall damage
Figure 3, #5	City Hall	URM, brick	mod.	cracks and damage to 2nd story
Figure 3, #6	City Shop	URM, brick	mod.	deep crack full height of bldg.; corner damage
Not Shown	Latter Day Saints Church partially	reinf. CMU	mod.	beam connection damage, displaced wall
Figure 3, #3	High School Auditorium	conc./CMU/ brick	severe	broken connections/broken chimney
Figure 3, #3	High School Gym	conc./CMU/ brick	severe	broken connections/URM wall
Figure 4, #15	Wells Chalet	URM, brick	heavy	bond beam and bricks fell from upper wall

Notes:

Total Nonresidential Building Count: about 80 buildings in Wells

* This is not a complete list of damaged buildings; other damaged buildings exist that were not visited because of time constraints.

URM – Unreinforced Masonry Building

CMU – Concrete Block Masonry Unit

ven. – veneer

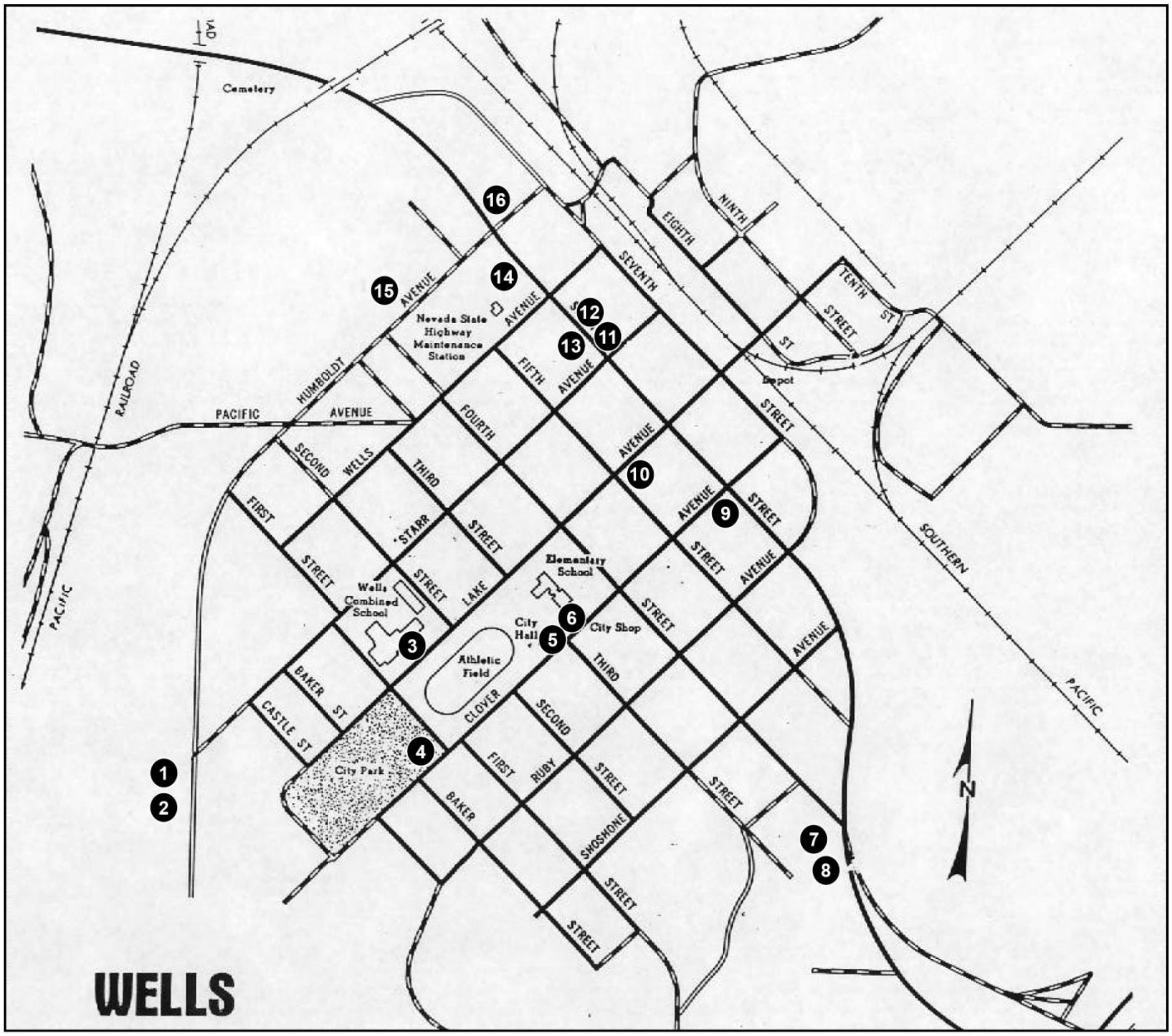
Buildings with Moderate or Minor Wall, Parapet, Crowning Bond Beam, Veneer, and/or Chimney Damage

Location	Building	Building type	Damage Level	Damage
Figure 4, #10	Bargain Barn/Elite Saloon	URM, brick	mod.	pounding, parapet and wall bricks fell
Not Shown	Brick Motel near NDOT yard	URM, brick	minor	few bricks thrown down
Not Shown	Building next to Overland H.	wood?	minor	few bricks thrown down from veneer
Figure 4, #11	Capitol Club	URM, brick	mod.	many bricks fell from parapet and wall
Figure 3, #11	Constable Powers bldg.	URM, brick	minor	parapet and upper wall bricks fell
Figure 4, #6	Eagle Club	URM, brick	mod.	broken windows, wall and bond beam damage
Figure 3, #6	Elko County Highway shop	CMU	minor	cracked walls
Figure 4, #9	Goble Market	URM, brick	mod.	upper wall failures, front and back
Not Shown	Laundromat Building	CMU	mod.	veneer damage, cracked parapet
Figure 4, #17	Luther's Bar building	CMU	mod.	roof and wall damage, parapet crack
Figure 4, #2	Meat Market	URM, brick	mod.	bricks fell from upper wall, wall cracks
Figure 4, #5	Murphy's Bar	URM, brick	mod.	major cracks, bricks from Nevada Hotel
Figure 3, #13	NDOT Yard Bldg., N. bldg.	CMU	minor	chimney damage, wall cracking
Figure 3, #13	NDOT Yard Bldg., S. bldg.	CMU	minor	corner damage, roll-up doors scrape
Figure 3, #12	Old firehouse building	URM, brick	minor	movement of roof system
Figure 3, #13	Old Theater	CMU	minor	chimney failure, upper-outer wall tilted
Figure 4, #18	Old West Inn	URM, brick	minor	section of upper part of wall failed, wall cracks
Figure 4, #19	Overland Hotel	wood, brick	mod.	bricks fell from front and side veneer
Figure 4, #12	Quilici's Market	URM, brick	mod.	upper wall failure, parapet damage
Figure 3, #8	Ranch House	part. reinf. CMU	mod.	broken wall and parapet
Figure 4, #20	Supp Garage	CMU	minor	corner damage
Figure 3, #4	Wells pool building	CMU	mod.	wall cracking, pool liner damage
Figure 4, #1	Wells Progress building	wood/brick ven.	mod.	brick wall moved out near upper part

Buildings with Other Nonstructural Damage**

Location	Building	Building type	Damage Level	Damage
Figure 3, #15	Wells Rural Electric	steel/concrete	mod.	ceiling tiles and supports fell
Not Shown	Bonneville Translocator	steel	mod.	ceiling tiles and supports fell on 2nd story
Figure 3, #7	Motel 8	steel	minor	broken windows, wallboard cracking
Figure 4, #14	Frontier Apts.	wood/concrete	minor	broken windows, wall board damage
Figure 3, #1	Stuart's Market	steel truss/ CMU walls	minor	ceiling tiles and supports shifted
Figure 3, #2	Hardware Store	steel truss/ CMU walls	minor	ceiling tiles, major content loss
Figure 3, #10	Justice Court	wood frame	minor	wall cracking

****** Does not include nonstructural **content** damage, which was widespread, unless content damage was major.



Wells City Map

1 Stuart's Market	8 Ranch House	15 Wells Rural Electric
2 Hardware Store	9 Supp Garage	16 Elko County Highway shop
3 Wells High School	10 Justice Court	
4 Pool building	11 Constable Powers building	Not Shown:
5 City Hall	12 Old Firehouse building	Historical District buildings
6 City Works	13 Old Theater	4-Way Casino
7 Motel 8	14 NDOT yard buildings	Bonneville Translocator

Figure 3. Location of downtown Wells buildings discussed in this report.

Wells Historical District Buildings

1. Wells Progress building
2. Meat Market
3. Mint Saloon
4. Nevada Hotel
5. Murphy's Saloon
6. Eagle Club
7. San Marin Hotel
8. Flag wall
9. Goble Market
10. Capitol Club
11. Bargain Barn
12. Quilici and Sons Market
13. Bullshead Bar
14. Frontier Apartments
15. Wells Chalet
16. El Rancho Hotel
17. Luther's Bar
18. Old West Inn
19. Overland Hotel
20. Supp Garage

Figure 4. Locations of Wells historical district buildings discussed in this report.

Totally and Partially Collapsed Buildings

Only one building, the San Marin Hotel, collapsed in its entirety from the earthquake (figure 5). This vacant building, originally built in 1899, was in poor condition and part of the back wall had reportedly collapsed in prior years. The building was stabilized following this back wall collapse using steel rods to prevent the building from falling on adjacent properties. Even though the building was in poor shape, the collapse from the earthquake was impressive and catastrophic.

The western wall of this two-story building toppled to the northwest, bringing the entire roof and second story down onto a brick-covered bottom floor and on top of the collapsed wall. The western wall totally disintegrated to a brick and broken-brick level. Window frames from the wall lay in the rubble field as isolated members. There may have been a dramatic contrast in the drift of this wall between the front and the back of the building because the front of the building was braced between the concrete block "flag wall" on the west and the Eagle Club on the east, and had a concrete beam/header at the first story ceiling level giving it support. The only small part of the western wall that remains is the lower front part. In contrast to the front, the back wall was free-standing on its western side.

Figure 5. Collapsed San Marin Hotel, viewed from the back. The western wall (left side) has collapsed bringing down the second story floor and the roof. Only the lower corners remain of the western wall. Displacement may have been limited in the more rigid front of the building which buttressed by a concrete block wall and has a solid concrete header beam over the open window front. The opposite remaining corner is badly cracked and rear of the building is reported to have partially collapsed before the earthquake.

The part of the bottom floor on the side that was not covered by the collapsed roof and second story, was strewn with bricks and debris from the collapsing eastern wall. With the exception of a small room near the back of the building, there was very little survivable space in the collapse (figure 6). The empty lot to the west of the collapsed building, where the western wall fell, was also covered by thousands of bricks, including bricks from the top of the adjacent Goble Market to the west of the lot.

The San Marin Hotel building appeared to lack internal walls or bracing that would have added some strength to the building and might have provided areas for survival if it had been occupied. Although the building had been tied together with iron rods, it had not been braced or reinforced. The iron rods were simply pulled out and bent by the earthquake and subsequent building collapse.

There were three partially collapsed buildings: the Nevada Hotel, where the upper part and roof partially collapsed; the Mint Saloon building adjacent to the Nevada Hotel, which received bricks from the Nevada Hotel's second story wall and had a collapsed roof; and the El Rancho Hotel, which lost parts of its upper walls.

The two-story Nevada Hotel had parapet and upper wall failures (figure 8), and a relatively rigid wood roof that was losing support during the earthquake and collapsed down to the ceiling joists. Most of the bricks fell away from the hotel and the inside appeared to be relatively undamaged. Two brick headers over second story windows and a panel between windows were broken, were out-of-plane, and were threatening to fall.

Figure 6. Roof rafters from the San Marin Hotel lying directly on the second story floor. There was very little survival space in this collapse.

Figure 7. Pre-earthquake condition of the Nevada Hotel. The view is to the southwest. *Photograph by Jack Hursh*.

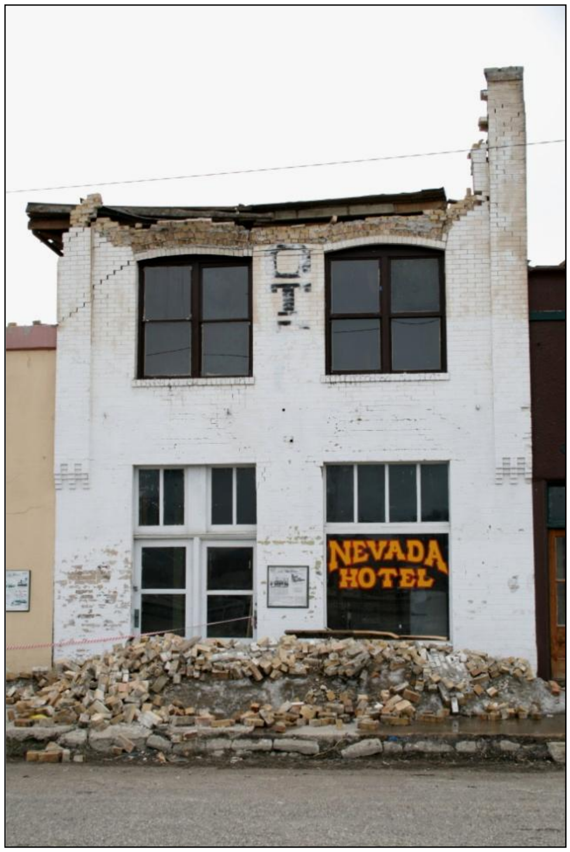


Figure 8. Earthquake damage to the Nevada Hotel. Fallen bricks from the front parapet and upper part of the wall are visible, as is the displaced roof. On the right (west) side of the Nevada Hotel is Murphy's Bar and on the left side is the Mint Saloon. Note that despite the damage to the hotel, the windows were not broken.

Bricks fell away from the top of the Nevada Hotel and onto the adjacent one-story Mint Saloon and Murphy's Bar. Over 85% of the Mint Saloon's roof was collapsed; bricks fell from the two-story Nevada Hotel onto the western part of the roof. This part of the truss-roof system failed, and it came down as a nearly single tilted unit, remaining attached on its east side and breaking up on its western side. There were a few meters on the western side of the Mint Saloon that were covered with debris, where the roof structure fell to the floor, and part of the wall was broken (figure 9). The part of the Mint Saloon where the roof didn't collapse was pierced by bricks on the western side.

The two-story El Rancho Hotel had severe upper-wall damage and slumping of the roof rafters where the support walls fell away. It is considered to be a partially collapsed composite unreinforced brick building; the composite nature of this structure includes having metal and wood frame interior with exterior unreinforced brick bearing walls. Damage was mostly limited to the outer walls of second floor and attic space levels where brick walls fell out, were severely cracked, or were vertically delaminated. Roof rafters were left suspended in air and slumped when their supports fell away. The building was occupied by seven people at the time of the earthquake, all sleeping on the second story; there were no injuries and all exited safely after the earthquake shaking was over. The interior structure had no significant damage with the exception of the outer edge of the upper floor wood frame. Significant amounts of bricks and debris fell from the El Rancho Hotel in the front and back of the building, and in the alley on the northern side.

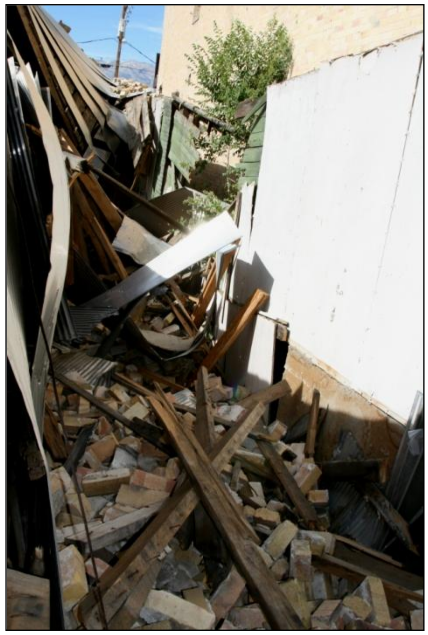


Figure 9. Collapsed western part of the Mint Saloon with bricks from the adjacent Nevada Hotel. The western wall has been broken in the center as well.

Figure 10. Inside the Mint Saloon with the collapsed roof system still hinged on the eastern wall.

Unreinforced Masonry Parapet and Wall Failure

The earthquake caused at least 13 buildings to shed bricks onto sidewalks and into alleys from parapets, walls, and gable ends. Fortunately, these locations were unoccupied when the early morning earthquake occurred. Wall and parapet failures were 0.5- to 6-m-high sections of bricks that tumbled to the ground from a height of one to two stories (3 to 10 m), in some cases creating rubble piles on the sidewalk as much as a meter deep.

Figure 11. Parapet and wall failure of an unreinforced wall at the back of the El Rancho Hotel. Most of the bricks fell next to the building, but note the one piece of bond beam that fell far enough to clear the crest of the adjacent house; scrapes on the house roof indicate other pieces of brick cleared this crest as well and slid to the ground in front of the house.

Figure 12. Failure of part of the front wall of the Capitol Club. The hole is in a wall that has three wythes of bricks. Above the hole the two outer wythes of bricks delaminated from the inner wythe, revealing a lack of cross-course bricks tying the upper wall together.

The gable unreinforced masonry ends fell out of the Goble Market (figure 13). These fell out like an unbraced parapet, and were attached only at the bottom to the roof system with a few anchor bolts. Movement of the roof system may have contributed to knocking the gables out.

Figure 13. The gable ends of the Goble Market failed. The hole reveals two roofs on the Goble Market, with an earlier pitched roof on a truss system. Damage stopped near a horizontal wood board attached to the building (this supported a wood-covered sidewalk the past).

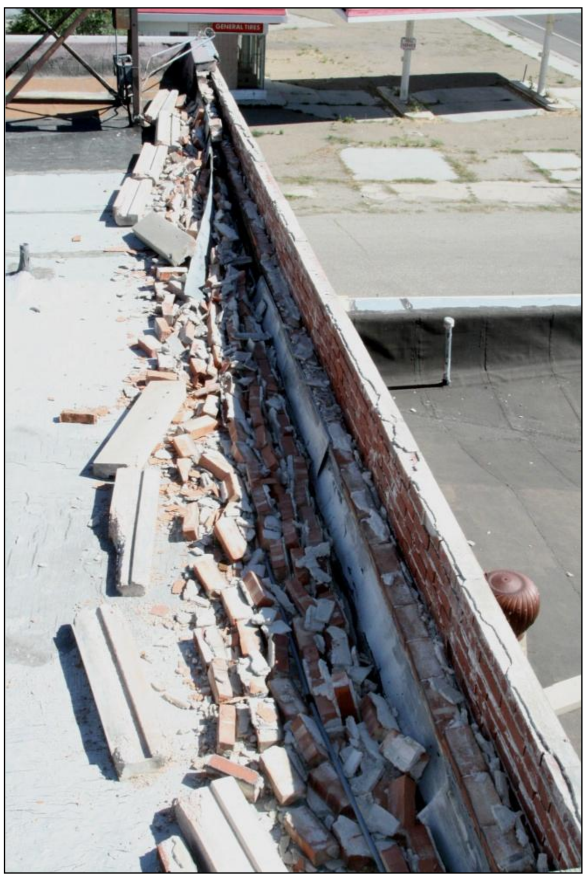


Figure 14. Parapet failure onto the roof of the El Rancho Hotel. The parapet appears to lack cross-tie bricks and the inner wythe of bricks has delaminated and fallen onto the building, along with the crowning concrete bond beam that capped the top of the parapet/wall.

Figure 15. Failure of the parapet and upper wall of the eastern side of the Nevada Hotel. The roof failure of Murphy's Bar was pre-existing from snow damage. The wall is laid down on the roof as if it fell out en masse. Even though over 25 courses of bricks fell on Murphy's Bar, where the roof was in place, it stayed up. The bricks fell a distance of about half a story. The Nevada Hotel and Murphy's Bar share a common wall.

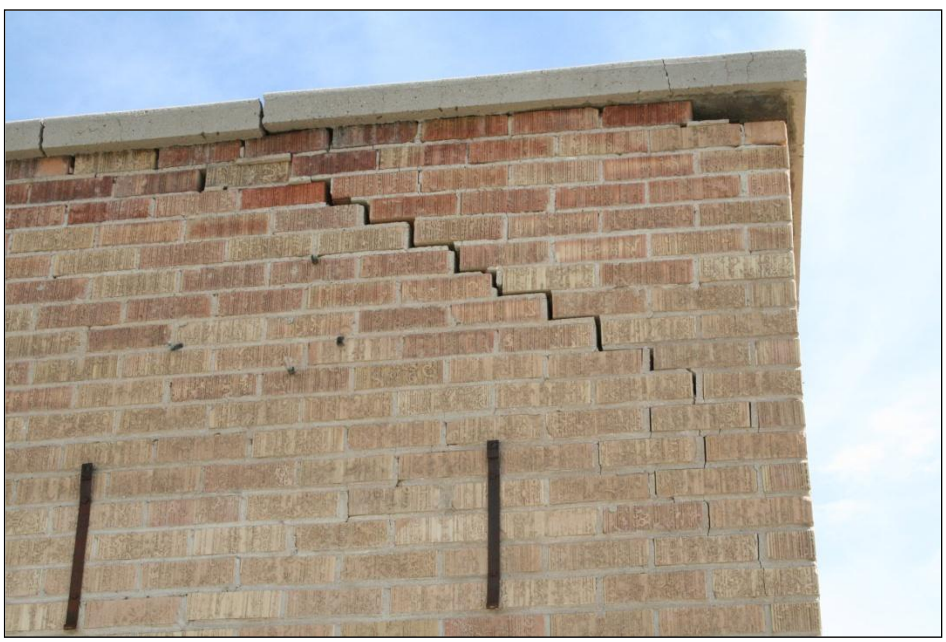


Figure 16. Concrete bond beam on the top of an unreinforced masonry wall at the back of the Eagle Club. The beam was used to stabilize the top of the wall. The bond beam is usually attached to the wall with only mortar at its base.

One particularly spectacular type of failure that occurred in several buildings was the toppling of the crowning bond beam from the top of the wall, either inwards onto the building's roof or outwards onto the adjacent building or sidewalk. When these bond beams fell all the way to the sidewalk, commonly with a few bricks stuck to them, they were very damaging (a graphic example of this is the crushed car shown in figure 17). Crowning bond beams in Wells were commonly placed on top of two-wythe-wide unreinforced brick walls that tended to be poorly cross-tied together in their upper parts. This made the upper part of the wall susceptible to delamination failure between the wythes of bricks, making it easier for the crowning beam to destabilize and fall.

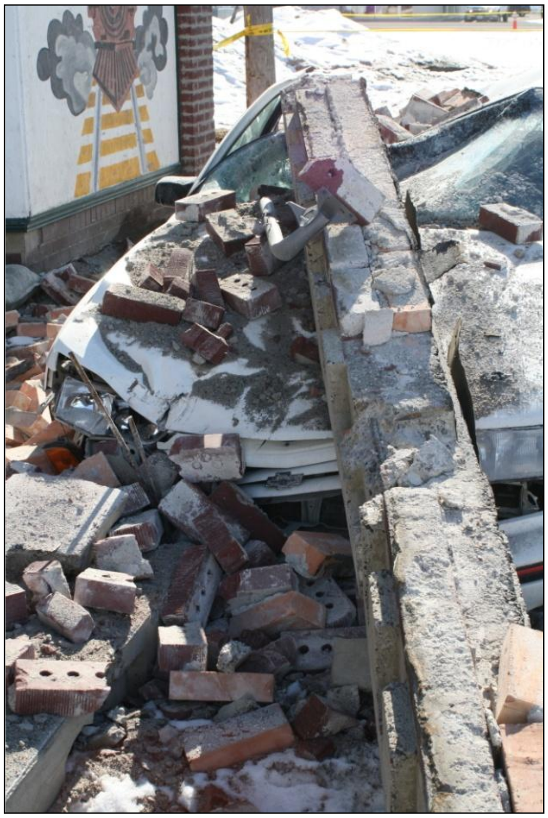


Figure 17. Crowning bond beam that fell from two stories and crushed a car. This beam was reinforced with two pieces of iron rebar and fell off in relatively large pieces.

Figure 18. Crowning bond beam section that fell off the Wells Chalet and likely broke up from uneven impact. Rebar in the bond beam can be seen. This is the same bond beam that is shown in figures 17 and 19.

Figure 19. Western side of the Bullshead Bar. The balcony has been smashed to the ground abruptly breaking the column connections and leaving the columns still standing. This likely happened because the balcony was rapidly impacted by the large, nearly intact crowning bond beam that can be seen in the photo. This is the same beam that crushed a car to the right of the area shown here (figure 17).

On several buildings, sections of the parapets and walls still standing are detached from their walls and appear ready to fall outward; many have a precarious appearance and have been threats due to aftershock shaking. In one case, the owner notes that the front veneer began leaning a while after the mainshock and may have been pushed out farther by aftershocks.

The parapet and wall failures have occurred in a few different ways: 1) walls and parapets appear to have peeled down, delaminated, or fallen as out-of-plane masses, 2) large and small failures of bricks where a crowning bond beam has toppled, possibly destabilizing or allowing the destabilization of walls, 3) free-standing brick wall failures, and 4) pounding failures.

In several cases where bricks fell out of URM walls, the resultant holes exposed poorly tied-together courses, courses that entirely lack cross-tying bricks, contacts with weak or missing mortar, poor-quality construction with rubble infill in the center of some walls, and poor materials, such as use of unfired and adobe bricks hidden in the inner wythes between regular bricks. Although it is hard to judge to what degree these factors contributed to failures, they certainly created even weaker unreinforced masonry conditions. They are also difficult to detect pre-event from a simple visual inspection of the walls because the sub-grade materials are usually inside the wall and are hidden by a wythe of regular bricks.

In nearly all cases of failure, the parapet or upper part of the wall was unsupported and unanchored to the building. It is particularly important to secure crowning bond beams to buildings because of the potential for these large structures to cause severe damage and injury if they detach and fall during an earthquake.

Figure 20. Separation and outward tilt of front wall of the Progress Building. This building has since been demolished.

Figure 21. Adobe and unfired bricks in the back wall of the Quilici Market. These were weak elements and were reduced to a pile of dirt when wetted. Notice the course of fired bricks on the far left side of the photo that covered up the unfired bricks.

Figure 22. Rubble infill (basically unlaid brick) in the unreinforced masonry wall at the back of the Quilici Market. This was covered by laid bricks and stucco (lower right center).

Figure 23. Rubble infill in the unreinforced masonry wall at the back of the San Marin Hotel. There were holes and gaps in this wall large enough to put a man's fist into, and several of the rocks were thrown in with no mortar in between them. The outer courses of laid bricks served as the forms for the rubble infill and hid this kind of construction from outside visual inspections.

Pounding Damage

Buildings in the historical district are immediately adjacent to each other, and in several cases appear to have reinforced or braced one another during the earthquake. But in some instances, differences in height, construction, or other response characteristics led to the buildings shaking out-of-phase with each other and pounding into each other. Two cases of pounding damage were noted, one between the Bargain Barn and Goble Market buildings and one at the Wells Chalet building, which had internal pounding damage. In the case of the Bargain Barn (white building in figure 24), the column was displaced to the west about 4 cm, possibly because the more rigid top of the Bargain Barn drifted farther to the east than did the column, shearing its top.

The Wells Chalet has a large concrete beam near the top of the second story that extends the entire length of the southern side. This concrete beam appears to have pounded out a hole in the Chalet's eastern unreinforced brick wall and may have impacted the upper part of the wall on the back of the Quilici Building, either by hitting the uppermost part of the wall directly or from falling bricks from the Chalet's wall.

Figure 24. Building pounding damage between the Goble Market and the Bargain Barn. The white column of the Bargain Barn is displaced about 4 cm over four courses of bricks.

Figure 25. A hole has been pounded out of the eastern wall of the Wells Chalet. The upper part of this wall is two wythes wide. Note how the crowning concrete bond beam on top of the eastern wall and some bricks overhang the concrete beam on the southern wall, giving a hole-like appearance to the damage; this failure does not appear to have peeled down from the top as many of the other wall failures did. The concrete beam appears to have pounded this hole into the wall. This pounding and the resulting falling bricks may have contributed to damage in the upper corner of the back of the Quilici Market. The blue tarps were put up the day of the earthquake to cover holes to protect the interior from weather.

Failure of Unreinforced Brick Veneers

There were two dramatic failures of unreinforced brick veneers that covered wood-framed structures. The brick veneer on the Bullshead Bar appears to have broken up and fallen as many pieces, whereas part of the front of the brick veneer on the Overland Motel appears to have cantilevered out *en masse*.

The Bullshead Bar building was veneered with brick in 1945. The bricks used each had three small holes in them that allowed some mortar to ooze in. The ties to the structure for the veneer were one- to three-nail clusters driven into two-by-four vertical wall studs every half-a-meter or so, and sticking out into the mortar joints of the veneer (figure 26). The part of the second story veneer that didn't fall shows several "X-fractures" that break the wall up every 30 to 50 cm (figure 27), apparently because the more flexible wood frame building was moving back-and-forth and breaking up the more rigid veneer. Many of the nails used as ties pulled out of the studs, but others remained. Several nail clusters used on the western wall retained a small amount of mortar when they stayed. This veneer was one wythe wide and served as a wall in half of the second-story northeastern front of the building. It had a fairly heavy concrete bond beam on top, which fell off in its entirety. The veneer on the front failed down to the first story, near where older bricks covered the first floor walls. On the western side of the Bullshead Bar building, the brick veneer also stripped down to the top of the first floor; here the same veneer continues down to the floor level. Most second-story windows and fairly heavy concrete sills that were set in the veneer wall also fell out.

Figure 26. Detail of the upper part of the front of the Bullshead Bar showing the wood frame structure and nails that were used to tie the brick veneer to the building. There were more nails; some were pulled out.

Figure 27. Large "X-fractures" in the remaining brick façade on the front of the Bullshead Bar show the break-up of the façade due to the rocking back-and-forth of the building. The lower, redder bricks are solid, older bricks. The darker bricks above have small holes in them (figure 28). The ledger for the balcony can be seen poking out on the right side of the building, just above the color change in the bricks.

Figure 28. Brick from the upper part of the veneer of the Bullshead Bar showing small holes for the mortar to go into. Cracks seen in figure 25 that cross both types of bricks do not show distinct differences in character when they do so.

Figure 29. The second story of the western wall of the Bullshead Bar where the unreinforced brick veneer has fallen off. The darker areas on the white wall are where nails, either single or clusters of nails up to three in number, were driven into the wall studs. This was how this one-wythe-wide veneer was attached to the building.

At the Overland Hotel, bricks fell off the front of the building (across the entrance) and off the eastern side (figures 28 and 29). The front pane glass window also shattered over a bench in front of the building, which was unoccupied in the early morning hours of the earthquake. Small metal attachment strips remained on the building, which were tying the veneer to the structure. During the clean-up, the rest of the bricks were taken off the structure and the front was covered with stucco and painted.

Figure 30. Failure of an unreinforced brick veneer on the Overland Hotel.

Figure 31. Failure of an unreinforced brick veneer on the Overland Hotel. The ordered nature of the bricks indicates much of the veneer fell out *en masse*.

Damage to Wood-Framed Structures

The wood-framed structures in Wells are mostly single-story buildings, although at least three were two-story. All weathered the earthquake structurally intact, but there was commonly nonstructural damage.

Exceptions of damage include the Bullshead Bar and the Overland Hotel which are wood-framed buildings with two-story-high unreinforced brick cladding or veneer (the Bullshead Bar building is actually a composite structure with an eastern bearing wall made of unreinforced brick). The wooden frame portion of these buildings seems to have survived without significant damage, but at least one, the Bullshead Bar, had additional internal wood framing added to the building. Much of the second-story unreinforced brick veneer failed from these buildings, however, and fell to the sidewalks below (see discussion of brick veneers).

Figure 32. Wood frame of the Bullshead Bar exposed at the northwest corner of the building where the brick cladding has come off. The remaining cladding is damaged and ready to fail, which would also allow the concrete window sill to fall.

Figure 33. Interior of the Bullshead Bar showing the wood-frame structure. There are new wood braces (pre-earthquake) to help secure the building during construction. Note the leaning glass and other items on the first floor that did not topple or break. The wood reinforcing frame may have helped to keep the building from collapsing during the earthquake.

The Frontier Apartments, a composite two-story wood-framed, railroad tie, and concrete building across the street from the Bullshead Bar, survived the earthquake with only minor damage and was green-tagged for general occupancy about a week after the event. It had 10 broken windows, numerous cracks and fractures in plaster, and a few areas were the plaster fell off wood lathing. Three people were knocked out of their beds on the second story of this building; one of these people estimated that one foot of displacement occurred to knock him out of bed.

Figure 34. The Frontier Apartments are in a composite wood/railroad tie/concrete building in old town that survived the earthquake fairly well, although it had some nonstructural damage.

Figure 35. The eastern portion of the building had racked and fallen plaster.

Damage to Concrete Block Masonry Structures

There are many concrete block masonry buildings, commonly called CMUs (concrete block masonry unit) in Wells. In most instances there was no way to determine the amount of reinforcement that was or was not present. In most cases, these structures performed well, including two concrete block buildings in old town, which are adjacent to damaged buildings. Most of these buildings are single story, although there are a few two-story CMU structures in town.

There were shaking cracks in several CMU buildings, but most of these appeared to be cosmetic. There was also some general nonstructural damage to several of these buildings, consisting of damaged chimneys and broken windows.

Figure 36. Damaged corner of the concrete block Supp Garage.

Figure 37. Broken concrete block brick and cracking in the upper corner of a Nevada Department of Transportation garage building in Wells.

Figure 38a. Cracking in the inside corner of a Nevada Department of Transportation garage.

Figure 38b. Close-up view of the cracking shown in figure 38a.

Figure 39. Patched cracks in the eastern wall of the Elko County Highway Department building. Cracks are between the blocks and show some crude "X" patterns.

Figure 40. Southern side of the same building shown in figure 39, also showing patched cracks.

Figure 41. Patched cracks in another concrete block masonry building at the Elko County Highway Department compound; northern wall is shown.

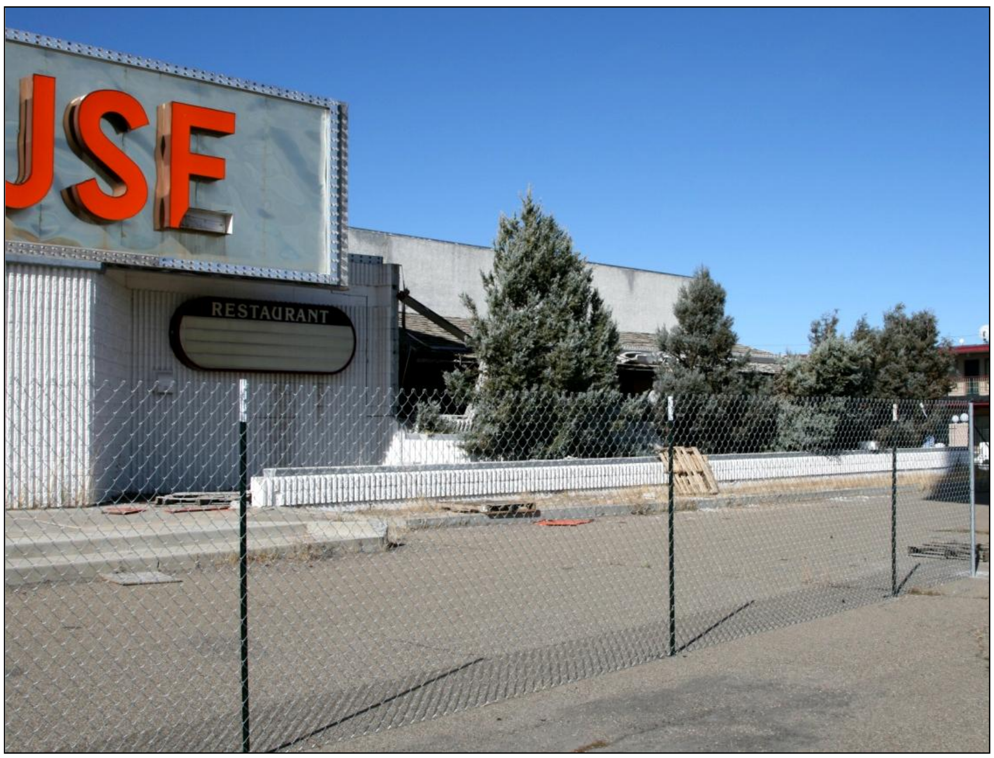


Figure 42. Damage to the concrete block front of the Ranch House. The wall behind the trees has fallen away; the wall is shown in figure 43.

Figure 43. Failure of a concrete block wall away from the structure at the Ranch House Casino. There were a few vertical reinforcing pieces of rebar in the wall.

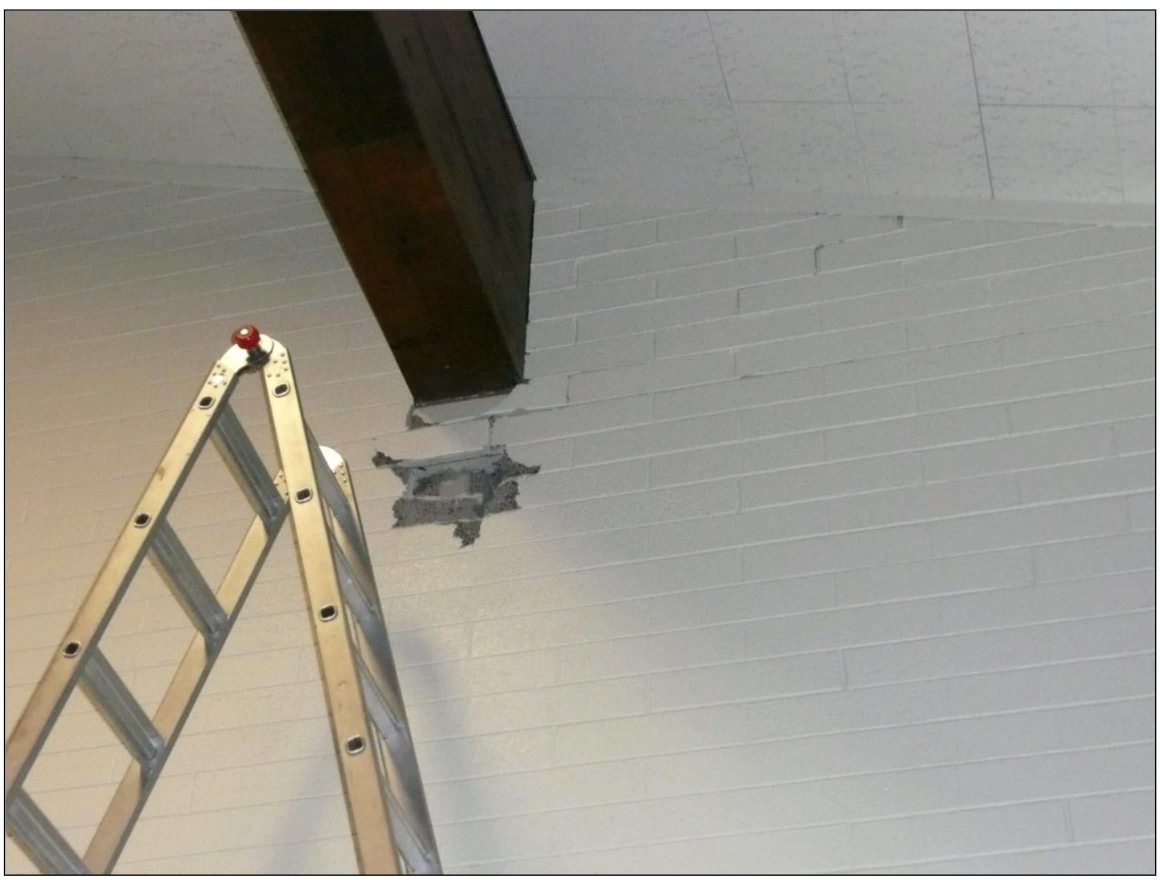


Figure 44. Damage to concrete blocks under a large glulam support beam in the Wells Ward LDS church. A column of concrete should have been poured under the beam, but the blocks were only partially filled with concrete. *Photograph by Glen Palmer*.

Damage to Unreinforced Masonry Buildings

There are approximately 16 unreinforced brick-masonry nonresidential structures in Wells, and three other buildings that were of composite construction that includes parts that are made of unreinforced brick, for a total of 19 brick URM or partial brick URM buildings. All showed at least cracking and minor damage and 12 of these buildings had major damage (63%), most of which was failure of parts of walls and parapets. One unreinforced brick building collapsed, one partially collapsed, and one of the composite buildings that included unreinforced brick walls partially collapsed from the earthquake (17%); this is close to the 20% value given in FEMA (2009). The terminology of unreinforced brick versus unreinforced masonry is used in this section because it characterizes the heavily damaged buildings in Wells, where the masonry is brick. Other types of URM construction were not comprehensively considered because of time limitations, but generally appeared to have less damage.

There were some potential differences in the damage patterns of the unreinforced brick buildings. For example, the Wells City Hall and Wells Public Works buildings (both two-story buildings) had comparably less damage than two-story buildings in the historical district. These damage differences could be due to building maintenance, building details (number of interior walls for example), and/or differences in local site conditions that led to different characteristics of the shaking. Preliminary measurements of V_{s30} shear wave velocity indicate 297 to 303 m/s for the historical district, whereas the velocity measured at the Wells City Hall was 358 m/s (O'Donnell and others, this volume).

The El Rancho Hotel was the only damaged composite unreinforced brick building that was occupied during the earthquake (it is a compound metal/wood interior frame with unreinforced brick outer walls). One occupant counted and said that shaking lasted for 40 seconds on the second story of the hotel. The brick bearing walls are two wythes wide near the top and had an uncertain width to the lower part. All the walls were cracked and had displaced bricks and three of the four walls had moderate-sized failures of their upper parts. The people inside were uninjured, threatened more by falling contents than by the structure, and were able to leave safely after the shaking stopped. A few more seconds of shaking may have changed this, however, because some of the most severe damage to the building was near where some of the residents were located.

There were many temporary wood columns used throughout old town to prop up failing ceilings and floors, to add strength to the roof systems for snow loads and support the buildings during refurbishing; the wood columns were toed in with nails at the top and bottom and sometimes supported beams spanning in between them. In the case of the Bullshead Bar, this interior framework replaced the interior walls that normally might have existed, but had been torn out. None of the interior wood braces that I observed had failed during the earthquake (figures 45 and 46). Wood bracing might be considered as a temporary measure for stabilizing URM buildings by engineers because it can be installed into buildings relatively easily and inexpensively. The El Rancho Hotel had an interior wood frame; this frame supported the roof, which did not collapse even though the roof joists were projecting out into space in places on the sides where the wall had collapsed away.

Figure 45. Bracing under the ceiling joist connections and roof. This example is from the Eagle Club.

Figure 46. Interior wood bracing in the second story of the Bullshead Bar; the first story had bracing as well (figure 33).

Balconies and covered sidewalks are common around older unreinforced masonry buildings, and although the balcony around the Bullshead Bar collapsed, it might have been braced and reinforced in a manner that could have helped it survive and possibly help protect people from falling bricks. The small balcony at the back of the Nevada Hotel stayed up and caught most of the bricks falling from the top of the wall, as did the awning of the El Rancho which was over a bench (figures 47 and 48). There are sturdy covered sidewalks around construction projects in cities. There could be an engineering analog that could be used around some types of URM buildings to help protect people from falling bricks until the buildings are rehabilitated. Standard rehabilitation measures, such as anchoring parapets, are the ultimate goal and covered sidewalks are not a replacement for such mitigation, but they may offer some temporary protection in the meanwhile for some buildings that can be economically achieved by building owners. The balcony of the Bullshead Bar that collapsed could have been better anchored to the building; if it had columns put on the building side and had some lateral bracing, it could have potentially stayed up.

Utility connections around URM buildings should be protected against falling debris during earthquakes, and possible collateral effects, such as leaking natural gas. In one case of a damaged URM building there were fallen bricks near a gas regulator, although none hit it. A more protected location or a steel cage that could deflect falling bricks and help prevent damage to the regulator might be a good idea to protect gas tanks and connections around URM buildings.

In most communities in Nevada, there are at least a few unreinforced brick or masonry buildings, and in some towns there are dozens. Until these buildings are strengthened for seismic shaking, they will likely continue to be a major part of the damage profile from future strong earthquakes that occur in or near these communities. Some ideas for reducing the earthquake risk of URM buildings, principally injury, property damage, and loss of use, are given in FEMA P-774 (2009).

Figure 47. An El Rancho Hotel awning protected two benches from falling bricks, despite its rather meager support.

Figure 48. The rear Nevada Hotel balcony caught every brick falling from the back of this severely damaged building.

Exits of Damaged URM Buildings

A significant amount of bricks and debris fell at many of the entrances and exits of the damaged buildings in the historical district as a result of the Wells earthquake (figure 49). A quick survey of the exits from 16 damaged URM buildings determined that out of a total of 36 exits, 21 exits (58%) had fallen debris and 15 exits (42%) were clear of debris. Two of the 21 debris-strewn exits had some overhanging protection from falling bricks: in one case it was a balcony and in the other it was the metal roof of an adjacent enclosed garage that served to protect the exits. Only 4 of the 16 damaged URM buildings had exits that were clear. In contrast to this, there was only one URM building that had few survival spaces left after the damage, and that was the collapsed San Marin Hotel. Most of the interiors of these buildings were clear of debris, which tended to fall away from buildings. Thus, in 15 out of 16 of the damaged URM buildings, any occupants would have survived the Wells earthquake by staying inside the buildings.

Figure 49. Bricks that fell across the back entrance of Quilici and Sons Market.

People in general would have likely survived better and suffered less injury if they stayed inside the damaged URM buildings than if they had attempted to exit the same buildings, based on the amount of debris that fell in these respective areas. Only one of the three partially collapsed buildings was occupied (El Rancho Hotel) by seven people, all of whom survived the earthquake without injury by staying safely inside during the shaking and exiting the building safely with emergency personnel after the shaking had stopped. Fifty-eight percent of exits of the 16 damaged URM buildings surveyed were threatened by falling debris versus 94% of these buildings' interiors were survivable from the 2008 earthquake. These observations support the advice to "Drop, Take Cover, and Hold On**,"** and **"**Don't go in or out of a building during an earthquake."

It is human nature for many people to instinctively react by running out of a building that is being shaken and damaged by an earthquake. The classic advice of earthquake scientists to "Drop, Take Cover, and Hold On" is counterintuitive to many confronted with the reality of an earthquake occurrence. Interviews with some of those who experienced the strong shaking of the Wells earthquake indicate that even in hindsight it would seem to them like a loss of control to stay inside and "do nothing" rather than run outside a shaking building. Hopefully, this report of the URM data and lack of total structural collapse of most buildings during the Wells event will encourage people to "Drop, Take Cover, and Hold On" in future earthquakes in Nevada and elsewhere. However, more can be done to protect people living in earthquake-prone areas.

In an ideal world with unlimited financial resources, all old URM buildings would be replaced with up-to-code construction or seismically retrofitted. However, most communities lack the economic resources to do this and will continue to occupy URM buildings in hundreds of communities similar to Wells throughout “earthquake country.” Until these buildings can be seismically rehabilitated, can low-cost measures mentioned in this paper, reinforced balconies and interior bracing, and elsewhere be used to reduce possible injury, even though they may only offer partial protection in truly catastrophic failures? Partial solutions are not appealing, but may be better than doing nothing if some lives can be saved.

CONCLUSIONS

Over half of the 80 nonresidential buildings in Wells were damaged by the earthquake, 17 of them severely. The worst damage was in the historical district to unreinforced masonry buildings (URMs), one of which collapsed and two of which partially collapsed. Nearly all of these URMs were made of unreinforced brick or were composite buildings with unreinforced brick parts. Examination of damaged buildings revealed many pre-existing structural weaknesses such as poor-quality building materials, lack of parapet and crowning bond beam anchorage, and poor building techniques, all of which likely contributed to making URMs more susceptible to seismic damage. Some of the most damaging components of the URMs were unsecured concrete crowning bond beams that fell as large pieces from the tops of the walls.

Some concrete block buildings had significant cracking damage from the shaking, but otherwise performed fairly well. There was one exception where blocks that formed a column under a beam appear to have been incompletely filled with concrete, and the wall under the beam was severely damaged.

Wood-frame buildings survived the earthquake well, but at least two had brick veneers that fell away from their second stories during the earthquake. One wood-frame building had a partially collapsed roof structure that had taken on falling bricks from an adjacent URM building.

Modern construction appeared to survive the earthquake well, although shaking cracks were found in all buildings throughout Wells.

Over half of the exits from 16 damaged URM brick buildings or buildings with unreinforced brick veneers in the historical district had bricks and debris thrown across them, indicating that it would have been potentially dangerous for occupants to have exited any of these buildings during the earthquake. In contrast, only one of these 16 buildings had minimal survival space inside. In fact, one partially collapsed building was occupied, the occupants stayed inside during the earthquake, and they exited safely after the earthquake without injury. These observations support the advice of not running in or out of a building during an earthquake, even for some of the older buildings in Nevada. Unfortunately they also indicate that safety is not 100% ensured if you are caught inside a URM during a strong earthquake. Ideally, URM buildings in Nevada will be seismically rehabilitated if they are going to be occupied. Some ideas for seismic strengthening of buildings, including URM buildings, are given at: http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/02-02-EARTHQUAKE/1-BUILDINGS/E~-Mitigation-Measures.htm and in FEMA (2009).

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APPENDIX 1. DAMAGE TO SPECIFIC BUILDINGS FROM THE 2008 WELLS, NEVADA EARTHQUAKE

Buildings Included in this Section

- Bargain Barn/Elite Saloon
- Bullshead Saloon
- Capitol Club
- Wells City Hall
- Wells City Shop Building
- Constable Powers Building
- Eagle Club
- El Rancho Hotel
- Goble Market
- Meat Market
- Mint Saloon
- Murphy's Bar
- Nevada Hotel
- Old West Inn
- Quilici and Sons Mercantile
- San Marin Hotel
- Wells Chalet

Bargain Barn/Elite Saloon

The Bargain Barn (formerly the Elite Saloon) was an operating store in the historical district. A large, sheet metal cornice fell off the top front of the Bargain Barn from just above the name along with several bricks, and a couple of the front windows were broken. Although a minor amount of merchandise thrown off the shelves and onto the floor, most of the merchandise stayed on the shelves along the walls and on the free standing shelves, which was surprising, given the earthquake damage to the historical district and the front of the Bargain Barn itself.

An interior brick wall near the back of the store showed some cracking and some plaster had been knocked off from the shaking (figure 56). The overall threat of injury from the Wells earthquake inside the Bargain Barn was low.

Figure 50. Front of the Bargain Barn store showing a couple of broken windows. The area above the sign is where the decorative cornice fell out. The broken windows on the left side of the store front in the picture are next to a column that was displaced at its top.

Figure 51. The cornice that fell from the top front of the store lies immediately across the entrance in an upside-down-and-backwards position. The cornice itself is made of metal sheeting, metal and wood, and was mounted into the unreinforced brick front.

Figure 52. Top of front wall of the Bargain Barn where the cornice pulled out. Note the paint outline. This western side of the parapet didn't fail but was badly damaged.

Figures 53. Pounding damage to the eastern wall of the Bargain Barn.

Figure 54. Closer view of the column in figure 53. This front column was pounded and displaced about 4 cm to the west over about four courses of bricks.

Figures 55. Interior nonstructural damage in the Bargain Barn. Although several items fell to the floor, most remained on the shelves. Ceiling tiles remain in place, hanging lamps and the suspended metal heating unit all are still in place.

Figure 56. The back wall of the Bargain Barn shows broken Plaster, which reveals an unreinforced brick wall, probably an old back wall.

Figure 57. Close-up views of the shelves and stock in the Bargain Barn. Most merchandise remained on the shelves in this single-story building. The floor is only partly covered.

Figure 58. Another view of the interior of the Bargain Barn.

Bullshead Saloon

The Bullshead Saloon (also called Bullshead Bar) is the oldest business establishment in Wells, originally built in 1869. The building that exists there today was built in 1900 and veneered in 1945. The building is a brick-veneered wood-frame structure, with a three-wythe-wide unreinforced brick wall on its eastern side. The eastern side is buttressed by the Quilici and Sons Market and the southern side is a common wall with the Wells Chalet, whereas the western and northern sides are free-standing. The east wall is a common wall with the market.

Figure 59. The northeast corner of the earthquake-damaged Bullshead Saloon with its dislodged sign.

Figure 60. Front of the Bullshead Saloon. The collapsed white balcony extended the entire length of the building before the earthquake (figure 61) and had been attached with hangers near the top of the brick facing (where the second story begins). During the earthquake, the brick façade and some parts of the crowning bond beam fell onto the front balcony, collapsing it. The balcony did not appear to disintegrate – rather it fell as a series of masses. In the front of the Bullshead, the balcony pulled away from the building and collapsed towards the northwest. The Bullshead has a western half of the second story that has a wooden wall (right half in photograph) and an eastern half that is an open area, previously covered with a brick wall. The thin, brick wall covering the open area was relatively unsupported.

Figure 61. The Bullshead Saloon before the earthquake. The front is on the left side and the western side is on the right. The balcony surrounds the building and the bond beam can be seen on the top of the wall. *Photograph by Sue Chapman*.

The main damage to the Bullshead Saloon was the falling of sections of the crowning bond beam, the falling away of a brick wall (across the open area in the front second story in figure 60 and 62), and the falling away of brick veneer from the second story. On the front (northern side) of the building, one section of crowning bond beam near the eastern side was laid on top of the building, and the rest fell outwards onto the balcony. On the western side of the building, all of the crowning bond beam fell outwards up to a meter from the building and came down as a single unit, much of it hitting and "instantly" collapsing the balcony below it (figure 19); this bond beam is concrete with two pieces of steel rebar in it. Windows, window frames, and window sills fell out of the second story and windows were broken on both the first and second stories. One second story window on the western side showed classic X-fractures (figure 69), reflecting the rocking back-and-forth of the building. First-story windows may have been principally damaged by falling debris.

Two brick walls were damaged at the Bullshead Saloon: the eastern wall–a three-wythe-wide unreinforced brick wall; and a brick wall covering the large opening on the front second story of the building. The eastern wall has major cracks with two gaping holes in it, but it stayed together (figures 62 and 63). The wall across the open area on the second story in the front of the building may have only been one or two wythes wide and mostly fell out onto the balcony.

Figure 62. Upper eastern corner area of the front of the Bullshead Saloon. The open area of the second story can be seen, along with part of the eastern unreinforced brick wall, badly cracked near the corner. A section of the bond beam can be seen on the roof.

The relatively brittle brick veneer on the second story was put on the outside of the Bullshead Saloon in 1945 and was anchored to the wood studs and columns of the building with long nails stuck out into the veneer mortar (figure 64). The brick veneer was deformed into pieces from the shaking of the more flexible wood-frame structure (figure 65), and fell onto the balcony, the sidewalk, and the street.

Figure 63. Close-up picture of damage to the eastern wall near the front corner. The wall is cracked, including a large crack that flowers into a hole near the top. The roof is detached from the wall and appears to have moved back-and-forth over it.

Figure 64. Detail of the upper part of the front of the Bullshead Saloon showing the wood-frame structure and nails that were used to tie the brick veneer to the building.

Figure 65. Large X-fractures in the remaining brick veneer on the front of the Bullshead Saloon show the break-up of the façade due to the back-and-forth rocking of the building. The lower, redder bricks are older and are solid, whereas the darker bricks above have small holes in them (figure 66). Both types of bricks fractured similarly.

Figure 66. A brick from the upper part of the veneer on the Bullshead Saloon showing small holes for the mortar to stick into them and give the wall some lateral strength. Cracks seen in figure 65 that cross both types of bricks do not show distinct differences in character.

A white balcony extended the full length of the building. It began to receive major amounts of bricks and sections of the crowning bond beam collapsing it to the northwest in the front of the building, indicating it fell as a unit or a few units riding down on the tilting columns (note that if it had been pulverized by the bricks, it would have fallen directly down). On the western side, columns of the balcony were left standing and parts of the floor of the balcony were lying against the building as though the balcony was broken in half. On this side of the building, the bond beam fell off as one contiguous piece (figure 67). The impact of this on the outer part of the floor of the balcony appears to have rapidly broken the column supports and dropped the floor down, which is why the columns are still standing.

Figure 67. Western side of the Bullshead Saloon. The balcony was smashed to the ground abruptly by the crowning bond beam, breaking the column connections and leaving the columns standing. The large, nearly intact, bond beam can be seen in the central part of the photo and the lower right. This is the same beam that crushed a car to the right of the area shown in this photo.

Figure 68. Part of the western wall that shows where the brick veneer has peeled away. The dark areas in the wall are where the nails tied the veneer to the building (many still have the nails in them that weren't pulled out – the veneer probably broke up around them). The window frames and glass fell out with the bricks.

Figure 69. Broken window on the second story of the western wall that shows X-fractures from the back-and-forth distortion of the window.

Figure 70. Hanger that held the building side of the balcony up.

Figure 71. Eastern wall of the Bullshead Saloon. Contact between the roof and the wall. The roof is detached and is carried by the wood frame.

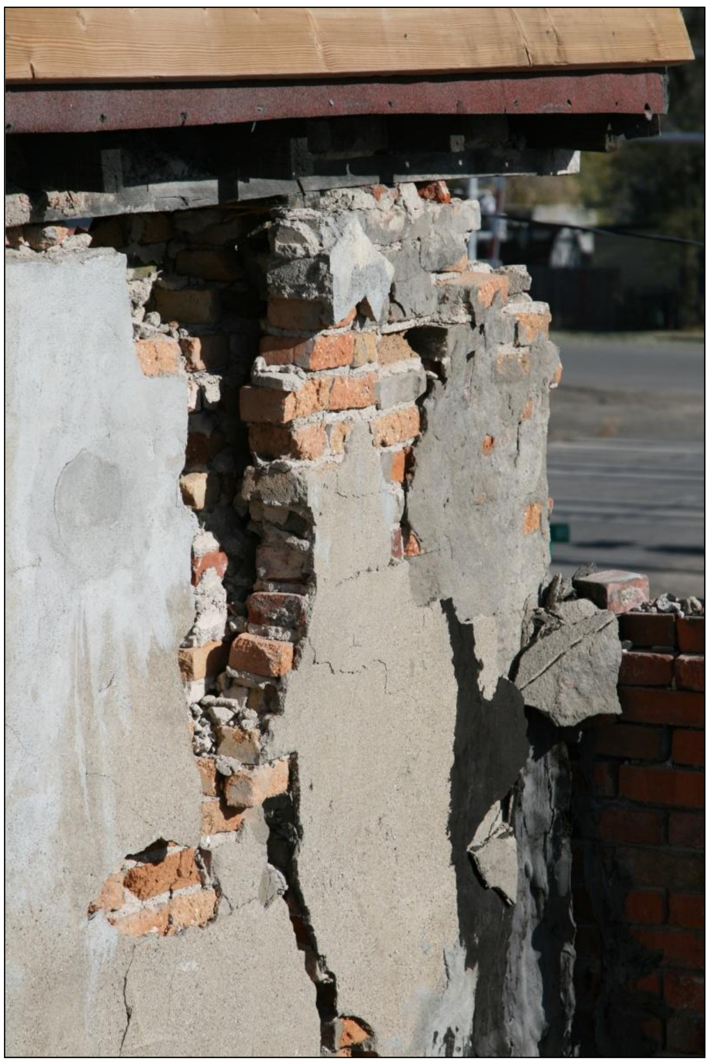

Figure 72. Detail of the broken northeast corner of the wall shown in figure 71.

Capitol Club

The Capitol Club suffered failure of the outer wythes of bricks from the upper 1 m of its front wall and a more serious failure of the entire wall in the northwest corner of the front. The building was built sometime before 1895. The outer two wythes of bricks appear to have delaminated from the interior wythe near the upper part of the front; there is a lack of cross-course bricks evident (figure 74). In the lower part, more crosswise bricks tying the wall together can be seen (figure 76). Some parts of the purple stucco wall that remain are badly cracked and appear ready to fall.

Figure 73. The front of the Capitol Club (purple building in the center with green trim and doors). The upper parts of the parapet and wall have failed and thrown bricks onto the front sidewalk, across the entrance.

Figure 74. The front of Capitol Club where bricks fell out. Note the even face of the upper part of the remaining wythe of bricks indicating a lack of cross-course bricks to tie the wall together.

Figure 75. Detail of the front wall. Several of the vertical contacts between bricks lack mortar.

Figure 76. Detail of bricks in the front wall of the Capitol Club. Some widely spaced cross-course bricks can be seen.

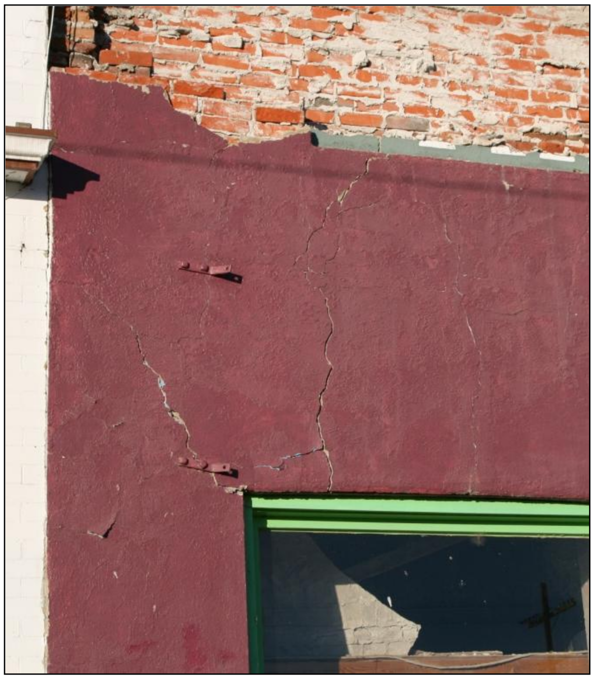

Figure 77. Part of the front wall of the Capitol Club that has not failed but is badly cracked. Note in the window that a part of an interior plaster ceiling has failed.

Figure 78. Interior of the Capitol Club showing few effects of the earthquake. The large bar back on the right is assumed to be unanchored to the wall. Note the fluorescent lights still hanging from the ceiling on relatively light-gauge chains.

Wells City Hall

Wells City Hall is a two-story unreinforced brick structure that is well maintained and in current use. There are several interior walls to this building, but in general these were not tied into the structure. The building received only minor damage from the earthquake that was visible on the outside, some breakage of bricks around a second story fire escape, some damage to bricks near the corner of the building, and some minor cracking. Engineering inspection of the building revealed two longitudinally split roof rafters, a displaced, unused fireplace, and some significant cracks in the concrete basement. Overall, however, the building performed quite well and was used immediately following the event. It will, however, require some significant repairs.

Figure 79. Wells City Hall.

Figure 80. Disrupted bricks above the second-story fire escape of City Hall.

Figure 81. Displaced fireplace in Wells City Hall; this can be seen in the crack between the upper part of the fireplace and the wall.

Wells City Shop Building

The Wells City Shop building is an unreinforced masonry building, with a large interior garage area. The building had a top-to-bottom crack on its eastern side (figures 64, 65, and 66) and some broken bricks at the top of the southeast corner (figure 67). This building was required for use immediately following the earthquake and the recommendation was given for only people needing to go into it for equipment do so quickly and spend as little time as possible inside because of potential aftershocks. Some interior framing may have helped give the building some support.

Figure 82. Wells City Shop building. The roof is supported by the unreinforced brick walls.

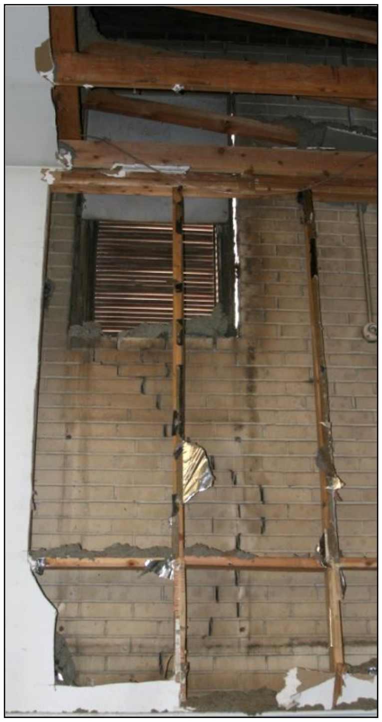

Figure 83. Wall crack shown in Figures 84 and 85 viewed from inside the city shop. There is a wood frame for the interior ceiling and walls.

Figure 84a. Cracking of the Wells City Shop.

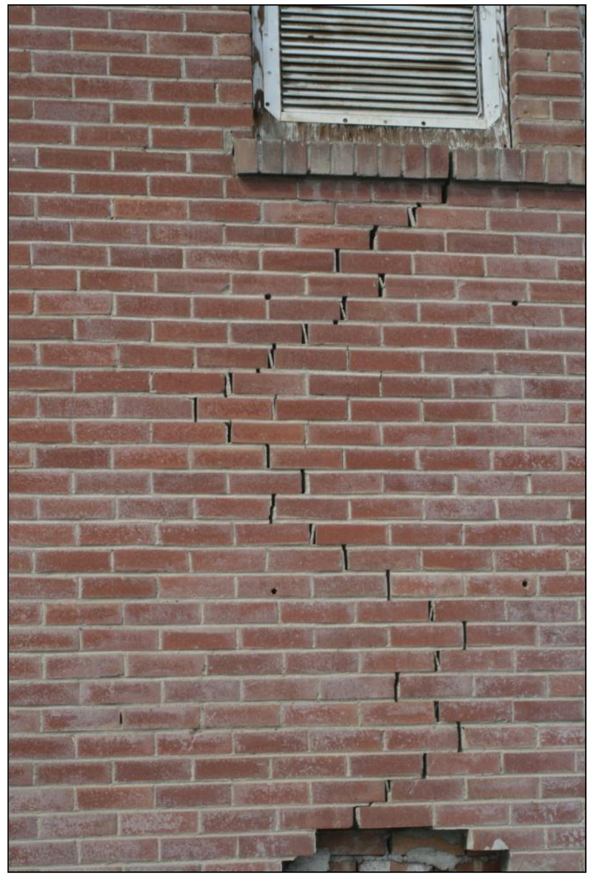

Figure 84b. Close-up view of the crack shown in figure 84a.

Figure 85. Cracking in the upper corner of the City Shop building, just below a wooden cornice.

Constable Powers Building

Bricks were thrown off of a small part of the Constable Powers Building, a small one-story unreinforced brick building. These bricks and a section of the crowning bond beam on top were part of a small parapet, all of which fell to the sidewalk near the back corner of the building. Some bricks also fell from an interior wall onto the building.

Figure 86. Fallen bricks and crowning bond beam from the parapet on the Constable Powers Building.

Figure 87. Parapet section that fell out of Constable Powers building.

Figure 88. Bricks that fell onto the top of the Constable Powers Building.

Figure 89. Part of the crowning bond beam that fell from the Constable Powers Building.

Eagle Club

The Eagle Club is a small one-story unreinforced masonry building that was built shortly after the 1901 Wells fire and had been added onto in the back at least twice. The building generally survived the earthquake fairly well, but suffered some roof damage, the loss of bricks and crowning bond beam from parapets in the back portion, and some badly cracked walls. The upper western part of its wall had been extended upwards with a wood frame built against the wall of the San Marin Hotel; this wall failed, exposing the interior of the Eagle Club to the weather. The sign in the front fell onto the front awning, but this reportedly happened prior to the earthquake.

Figure 90. Front of the Eagle Club.

Figure 91. Interior of the Eagle Club showing little earthquake damage and washing machine units in the upper right that did not topple.

Figure 92. In the photograph to the right showing the inside of the Eagle Club, the pipes on the cabinet surprisingly stayed up during the earthquake even though they were free to roll around.

Figure 93. The western wall of the Eagle Club. Although the wall has not failed, the adjacent wall of the San Marin Hotel failed, exposing the top of the Eagle Club to the weather.

Figure 94. Corner between the back wall of the San Marin Hotel and the Eagle Club. An inactive gas regulator was threatened by falling bricks (shown to the right and below). Active utilities need to be protected from falling bricks around unreinforced brick/masonry buildings, possibly with a protective cage.

Figure 95. Close-up view of the gas regulator shown in figure 94.

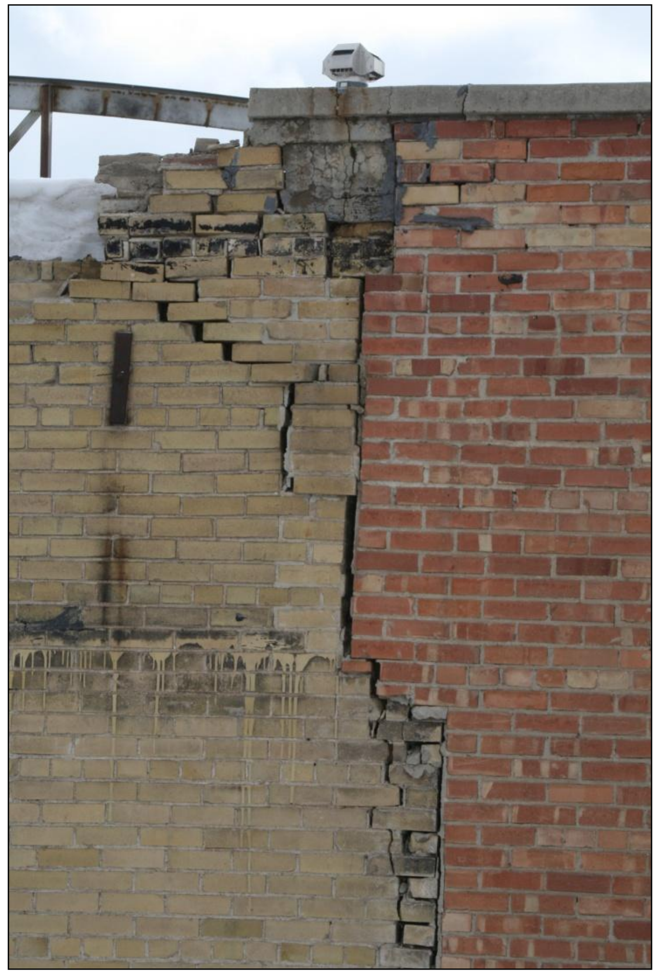

Figure 96. Damaged cold joint between two different added-on rear parts of the Eagle Club.

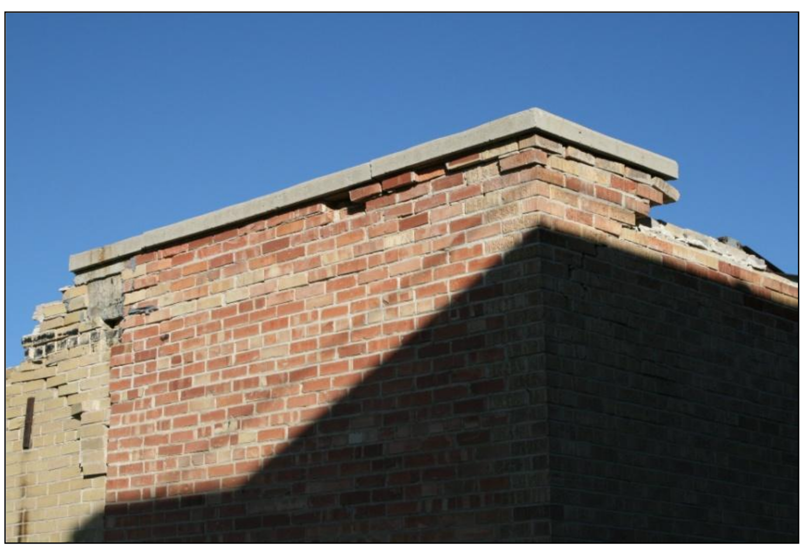

Figure 97. Remaining part of the crowning bond beam and upper wall near the back southwest corner of the Eagle Club.

Figure 98. Bricks and a part of the concrete crowning bond beam that fell from the Eagle Club.

El Rancho Hotel

The El Rancho Hotel was built in 1949. The hotel is a compound metal-wood-frame building with unreinforced brick walls. The metal frame exists in the basement and first floor, and the second floor is wood frame, as is a half-floor-sized attic. An unreinforced brick wall makes up the outside of the building and has slots that hold the outer parts of the floors. The wall extends above the roof with a small parapet and a concrete crowning bond beam on top. A large covered balcony was built at the second story level in the central part of the front of the building (figure 99).

Damage to the El Rancho was focused on the second story and included falling of crowning bond beams, delamination and failure of parapets, falling out of the upper parts of three walls, cracking and out-of-plane sections of brick walls and corners, slumping of part of the roof where the support from a failed wall was gone, severe interior cracking, and content damage and disruption. The building was occupied by seven people and shaking on the second floor was described as lasting for 40 seconds.

Figure 99. The front of the El Rancho Hotel before the earthquake. *Photograph by Sue Chapman.*

Figure 100. Earthquake-damaged front of the El Rancho Hotel.

Figure 101. Upper part of the front unreinforced failure brick wall that fell out.

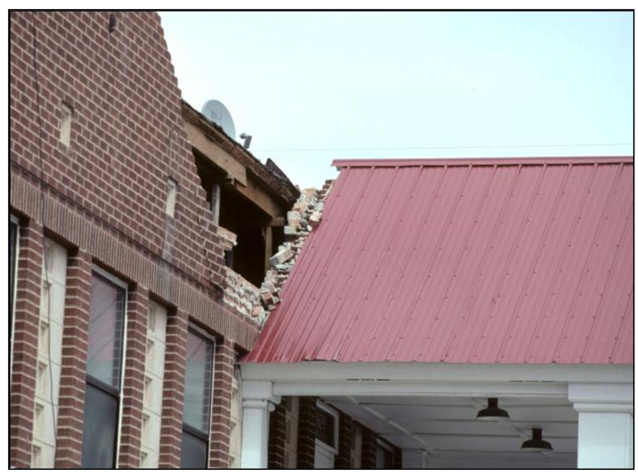

Figure 102. Close-up of upper wall shown in figure 101.

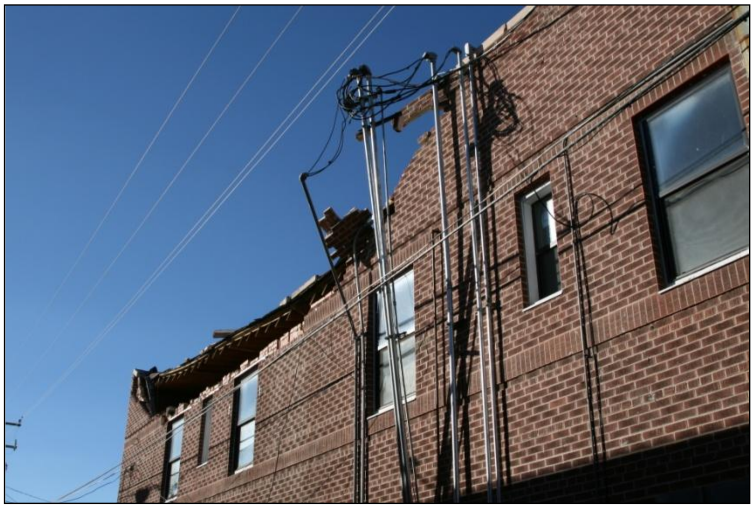

Figure 103. Failure of the upper part of the northern wall. A large section of the wall between the ceiling joists and the roof, including the parapet, fell out and damaged electrical masts to the building.

Figure 104. Close-up of the wall failure showing hanging roof joists, a section of bond beam on the roof, and the exposed ceiling joist connections.

Figure 105. Brick damage to the northwest corner of the El Rancho Hotel.

Figure 106. Ceiling joist connection exposed by water damage. The joist is unattached to the wall, but was found to have shifted only a few millimeters in this case, once the shaking had stopped.

Figure 107. The diagonal cut is a "fire cut" made so the cut would burn faster if there was a fire and drop the interior of the building without damaging the walls. With a longer duration of shaking, these connections might have started to fail.

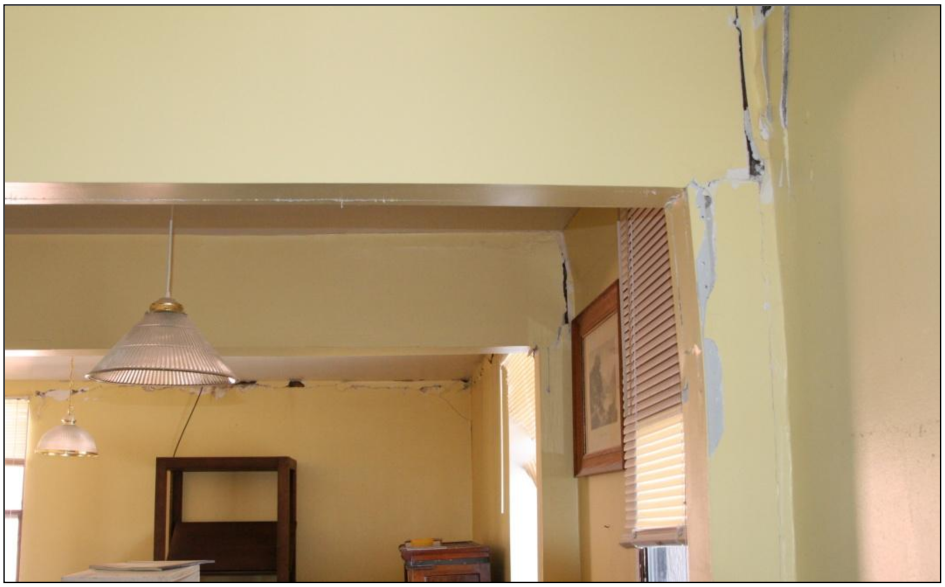

Figure 108. Severe cracking of sheetrock in the upper part of the second story of the El Rancho Hotel.

Figure 109. Severe cracking of sheetrock in the upper part of the second story of the El Rancho Hotel.

Figure 110. Severe cracking of sheetrock in the upper part of the second story of the El Rancho Hotel.

Figure 111. Nonstructural content damage to the El Rancho Hotel. *Photograph by Gene Kaplin*.

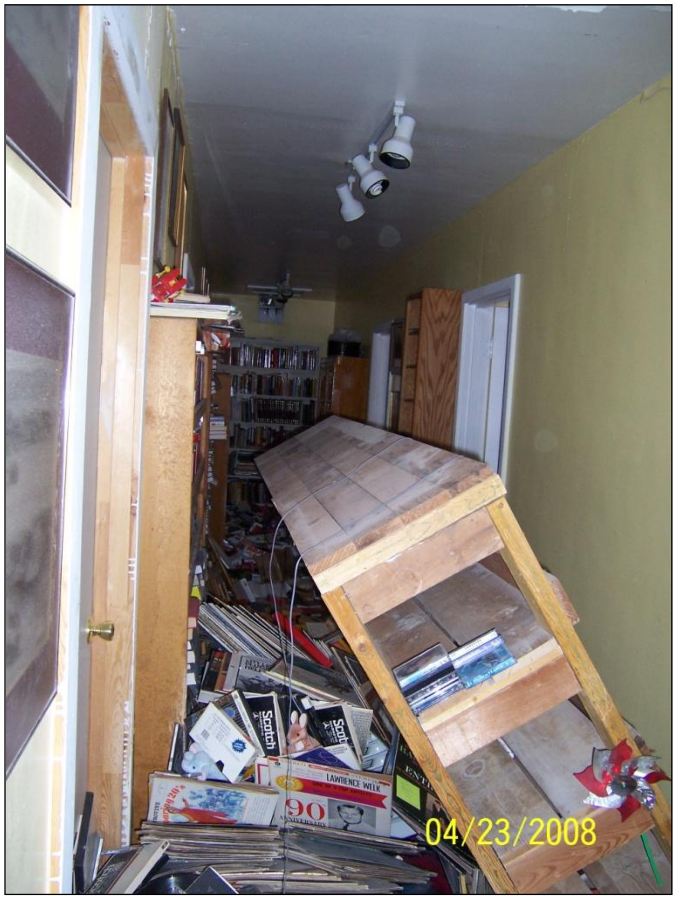

Figure 112. Nonstructural content damage to the El Rancho Hotel. *Photograph by Gene Kaplin*.

Goble Market

The Goble Market is an unreinforced brick building that was constructed before 1888. The upper gable parts of both the front and back of the Goble Market fell out during the earthquake and there was cracking of the stucco exterior. The front gable fell onto the sidewalk, across the front entrance. The back gable fell onto a newer metal shed that is adjacent to the market, partly collapsing the roof. Pre-earthquake photographs show that the front had two small ornamental towers on either corner of the front which fell down as well. The inside of the building was relatively undamaged.

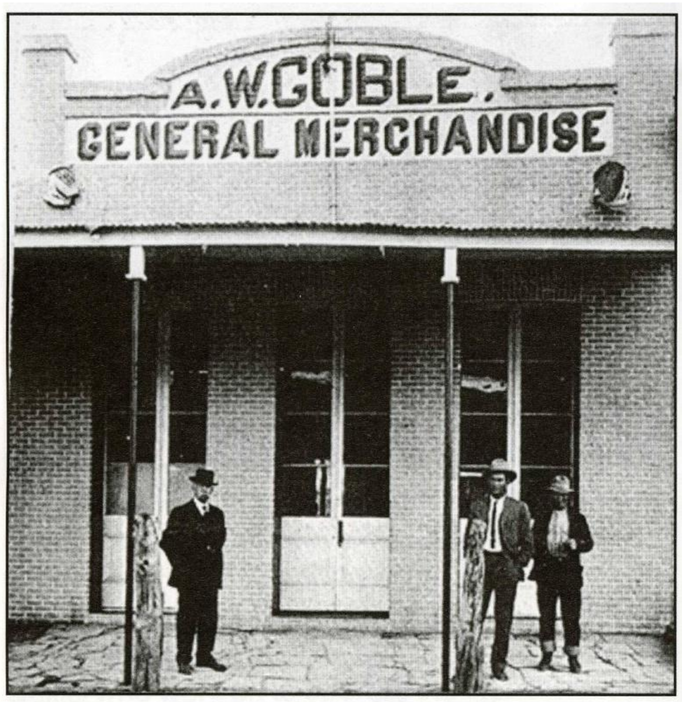

Figure 113. The Goble Market in 1888 is shown here. The two ornamental corners and the covered walk can be seen. *Photo from Old Town Front Street Walking Tour*.

Figure 114. Damaged gable front of the Goble Market.

Figure 115. Damage to the eastern wall of the Goble Market has exposed its construction. A later study of the broken wall revealed the cross course bricks that tie the wall together. These appear to be on end along the side of the wall. This is a three-wythe-wide wall. There were also some widely spaced bolts holding the wall to the structure.

Figure 116. Detail of the bricks of the front of the western wall of the Goble Market. Several vertical contacts between bricks are missing mortar.

Figure 117. Cracks in the front of the Goble Market.

Figure 118. Eastern wall of the Goble Market. Parapet failure of wall and the ends of tie rod anchors are visible.

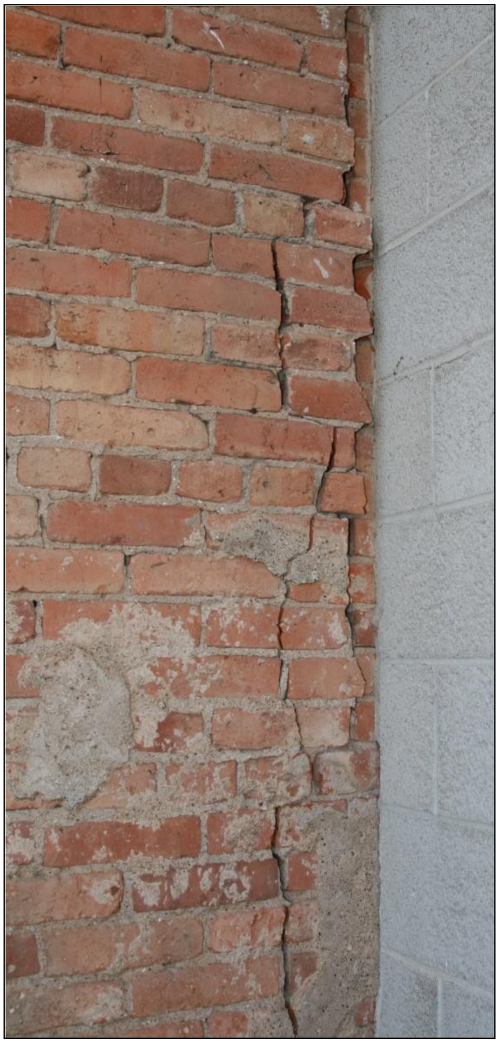

Figure 119. Cracked interface between the undamaged concrete block flag wall and the Goble Market, showing cracking.

Figure 120. Damaged southeastern corner of the Goble Market.

Figure 121. Failed rear gable and western parapet of the Goble Market. The brick wall was caught by the adjacent metal roof, which partially collapsed.

Meat Market

The Meat Market is a small unreinforced building built in 1902 that was cracked and had a small amount of parapet failure and failure of the upper part of the front wall. Bricks were shed onto the sidewalk and across the front entrance. Examination of the bricks remaining in the failure indicates that mortar was applied only to the horizontal surfaces and not the vertical ones, adding a weakness to this part of the wall. Out-of-plane tilting of part of the remaining upper wall indicates that it is close to falling out. There are also several moderate-sized cracks in the remaining brick front. An old wood hanger attached to the front for a covered sidewalk may have helped to stabilize the front wall during shaking.

Figure 122. Area of fallen bricks from the upper wall and parapet of the Meat Market.

Figure 123. Leaning top of the wall of the Meat Market.

Figure 124. Detail of brickwork from the failed part of the wall. Note mortar is used on the horizontal contacts between bricks, but is missing from most of the vertical contacts between bricks.

Figure 125. Inside of the Meat Market (an unused building) shows little damage, including ceiling to roof connections.

Mint Saloon

The Mint Saloon was a small wood-frame building with a square false front built in 1902 and remodeled in the 1930s. The building had a pitched roof behind the façade supported by a truss-roof system, and corrugated metal roofing. The building appeared to survive the shaking intact, but bricks from the Nevada Hotel fell two stories, penetrating parts of the Mint Saloon's roof and contributed to the collapse of the roof on its western side. Large parts of the roof system rotated down to the west as a unit, but the westernmost part of the uncollapsed portion was also crushed. About 40% of the inside of the Mint Saloon was survivable without collapsed parts.

Figure 126. Back of the Mint Saloon showing the remaining part of the roof. A large gap can be seen between this remnant and the front where the roof has collapsed. Bricks from the Nevada Hotel, on the left, collapsed the roof.

Figure 127. Back of the Mint Saloon. Holes can be seen in the roof where bricks have fallen through. The adjacent balcony that can be seen of the Nevada Hotel caught all the bricks that fell on that side.

Figure 128. Collapsed western portion of the Mint Saloon, exposing the western wall; part of the wall collapsed.

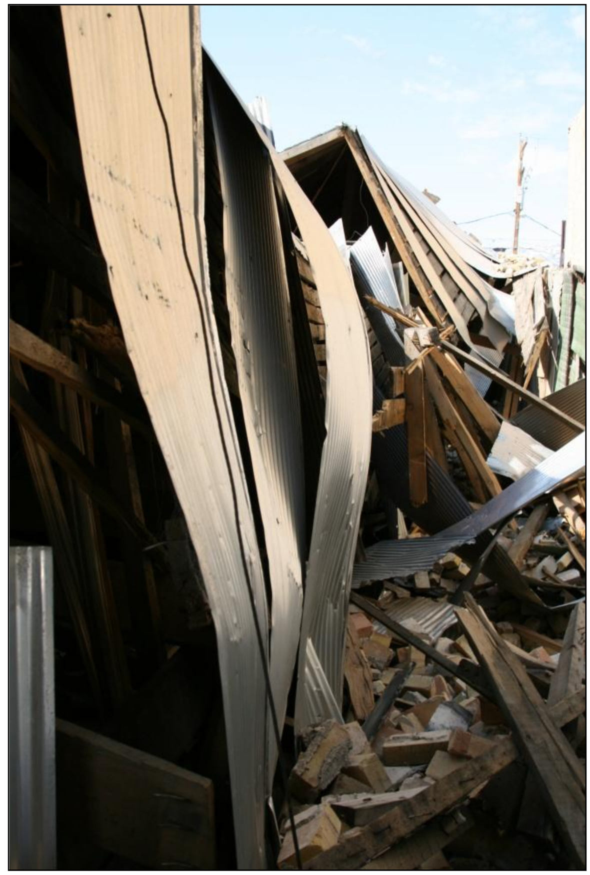

Figure 129. Collapsed portion of the Mint Saloon roof.

Figure 130. Bricks from the Nevada Hotel on the Mint Saloon floor.

Figure 131. Eastern portion of the Mint Saloon. This area was survivable. The collapsed roof system is in the upper right.

Figure 132. Tilted truss roof system showing it mostly collapsed as a unit.

Murphy’s Bar

Murphy’s Bar is a small building that shares adjacent common three-wythe-wide unreinforced brick walls with neighboring buildings. Wooden trusses that fit into holes in the walls carried the ceiling and roof, and there was one transverse, wood-frame interior wall at the back of the front room. The building is long, with two brick add-on extensions in the back. The structure was built in about 1900 and in the late 1960s and 1970s the back of the building was used as a bowling alley (this may also have contributed to weakened mortar bonds).

The back walls are unreinforced brick that is two wythes wide with a concrete bond beam on top. The front half of the Murphy’s Bar building is braced between the Nevada Hotel and the Eagle Club. In the back, the brick wall surrounds both Murphy’s Bar and the Eagle Club, and an interior wood wall divides the two buildings. Two large exterior metal trusses carry the back part of the roof. During a snowstorm, the central part of the roof of Murphy’s Bar had earlier collapsed through the first floor and into the basement (a former speak-easy during prohibition), however, during the earthquake, the roof actually survived a showering of bricks from the Nevada Hotel fairly well without any visible penetration.

The largest damage to the Murphy’s Bar was the loss of bricks, loss of parts of the bond beam from the back walls, and large-scale cracking of the walls.

Figure 133. Front of Murphy’s Bar. Only a couple of windows were cracked or broken.

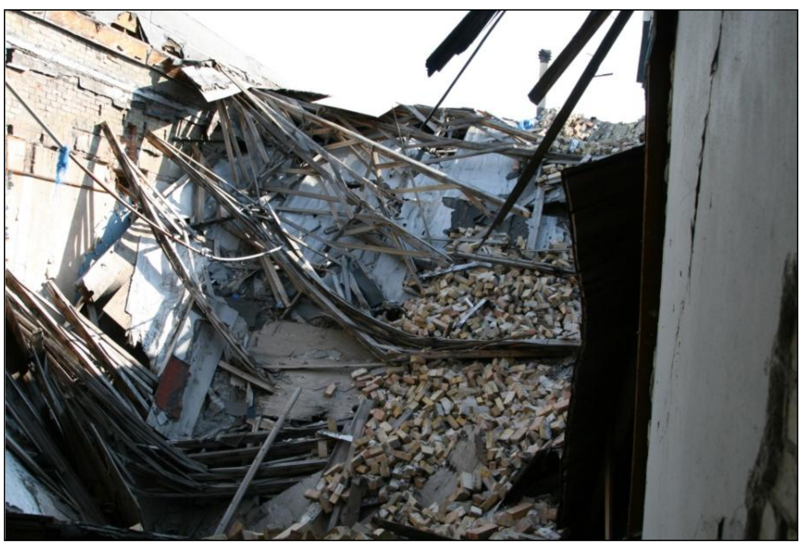

Figure 134. Bricks from the Nevada Hotel fell onto the roof of Murphy’s Bar which had previously collapsed from snow. Bricks can be seen around the stove pipe on the uncollapsed part of the roof indicating that the roof was able to handle the weight of the bricks.

Figure 135. Inside the front of Murphy's Bar. Note the stovepipe hanging down just to the right of center near the top. This is the same stove pipe visible at the roof in figure 134 that is surrounded with bricks. No bricks penetrated and there was relatively little seismic disturbance to the interior.

Figure 136. Interior of Murphy's Bar showing sheets of leaning glass that are unbroken by the earthquake. A cut in the wall in the background shows the unreinforced brick construction.

Figure 137. Detail of a roof rafter connection into the common wall of Murphy's Bar and the Nevada Hotel.

Figure 138. Fallen parapet at the back of the Murphy's Bar.

Figure 139a. Large crack inside the back door of Murphy's Bar.

Figure 139b. Close-up view of the large crack inside the back door of Murphy's Bar.

Nevada Hotel

The Nevada Hotel had major damage to the upper parts of its walls and parapets but there appeared to be limited internal debris and damage; bricks were shed outward from the hotel. The Nevada Hotel was built in 1902 and was used as a restaurant, hotel, and most recently as a "picture show house" (movie theater).

On the front side of the Nevada Hotel, the upper 0.5 to 1 m of parapet and wall fell out onto the sidewalk at the front of the building, including across the entrance (figures 140-144). In the front, the roof has fallen down about 0.5 m, been shifted to the east about 0.5 m, and appears to have come to rest on the ceiling of the second story. The brick headers over the two upper windows were cracked and the eastern one had been tilted out-of-plane and was hanging in a threatening manner over the front door (figure 143). Major cracks are evident starting at the location on the Nevada Hotel where the adjacent buildings brace it and trending upwards into the hotel towards the upper corner of the upper windows (figure 142). These open cracks, the eastern one on the alley side being the most prominent, indicate there was greater drift in the second story of the building than in the first story. However, incipient X-fractures between the upper windows and the lower window and door indicate serious movement occurred in the first floor as well. The door frame was being worked out of its opening in the wall, also indicative of strong ground motion (figure 144).

With all this damage and collapse in the front of the building, it is remarkable that no windows were broken in the front, including the moderate-sized plate-glass window that has the hotel's name on it (figures 141 and 144). The lower windows appear to have been protected within their frames. The upper windows were in the central part of the building with the large fractures being outboard of them. The damage was encroaching on these upper windows, and a couple more seconds of shaking likely would have threatened these windows with falling bricks or possibly with their frames falling out altogether.

The eastern part of the Nevada Hotel had four second-story windows that were boarded up. The upper parts of the parapet and wall fell down to the second-story ceiling level; these bricks fell onto the western part of the adjacent Mint Saloon's roof. The displaced Nevada Hotel's roof sticks out over its eastern wall about 0.5 m in the front of the building and near the rear of the hotel, the roof has shifted towards the interior of the building in an overall rotational manner. On the eastern side, the brick header of one of the windows is gone and another is tilted out-of-plane and is hanging in a precarious manner (figures 146 and 147). A panel between these two windows is tilted out-of-plane as well, towards the outside of the building. These two windows are in the central part of the wall and are near the pivot point of the roof's rotation along the eastern side.

The back of the hotel has two windows and a door (all boarded up) in the second story, a balcony, and a door flanked by two windows on the first floor (all boarded up). The roof collapsed in the back as well, but the wall and parapet were lower than the front and consequently fewer bricks fell out. Most bricks were caught by the balcony, which, except for the railing being knocked out of its eastern side, remained intact. The eastern corner of the building was severely damaged with the outer two wythes of bricks falling out (figure 148). On this part of the building, the only part of the wall in contact with the roof is a small panel of bricks balanced on a single brick that is between the door and the corner of the building (figure 148). The arch over the door and the arch over the outer window of the second story have fallen out. The western corner of the back also is missing the outer wythes, but it is still in contact with the roof. There is relatively little damage to the first floor in this wall.

The western wall was a large two-story wall, braced by the Murphy's Bar just above the first story level. This wall included several concrete block columns in the areas out of view from the front. In general, these columns remained and appeared to stabilize most of the unreinforced brick wall panels in between them, but they extended only part way up the wall (figure 149). About 2 m of the upper part of the wall fell to the west over 75% of its length. The only remaining part was about 1.5 m of the front of the wall. This western wall was only two wythes wide in its upper part. The remnant that remains is damaged and delaminated in part. The upper part of the wall appears to have fallen out *en masse*. This is inferred from the way the bricks are laid out in order on the remaining parts of the roof of Murphy's Bar.

The damage to the Nevada Hotel may have been partly influenced by having a braced northwest side (by Murphy's Bar), and an alley on the southeastern side (unbraced). The greater drift of the building allowed to the southeast by the unbraced side may have thrown the roof down in that direction; the tension crack located in the second story in the front wall, up from the braced front, is also larger on the eastern side. On the western side, bricks fell out down to deeper levels in the wall, possibly toppling out of plane as a unit. The concrete block columns stopped about ¾ the way up the wall, potentially leading to a contrast in strength and the response of the wall. The upper part of the western wall may have been significantly weaker and subjected to larger out-of-plane displacements because it is higher in the building, farther away from the concrete-block support columns, and was farther away from the bracing afforded by the adjacent one-story building.

Figure 140. Nevada Hotel between the Mint Saloon and Murphy's Bar.

Figure 141. Upper part of the Nevada Hotel. The roof collapsed down to the second-story ceiling level. The upper part of the front parapet and wall has completely fallen out and several parts were left out-of-plane.

Figure 142. Eastern side of the front of the building showing fallen (and pushed off?) parapet on the eastern side of the building, the roof overhanging in the front, and a large crack coming up diagonally from the adjacent support of the Mint Saloon's false front.

Figure 143. The brick arch over the upper window has lost the outer layer of bricks and is tilted out-of-plane. One of the major cracks comes up to its eastern base.

Figure 144. Bottom of the front of the Nevada Hotel showing bricks fallen from above. No windows were broken, but the frame for the windows and doors on the left is coming out of its opening.

Figure 145. First floor interior of the Nevada Hotel. The refrigerator and cash register did not fall. Most of the interior of the Nevada Hotel was not damaged although the second story could not be inspected.

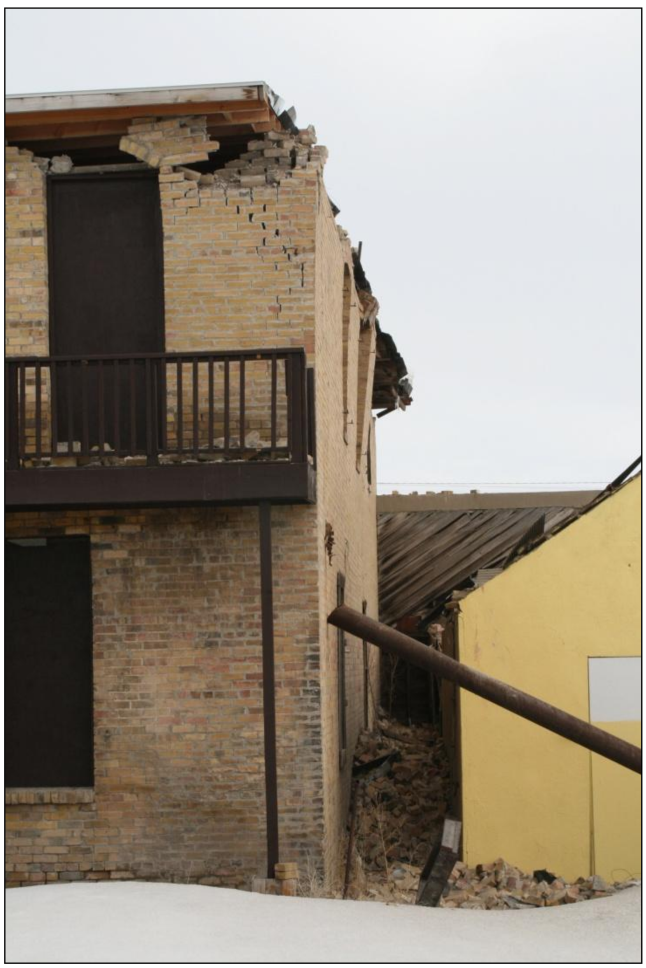

Figure 146. Eastern side of the Nevada Hotel showing rotated roof and out-of-plane parts. The balcony is on the back of the building and caught most of the bricks falling there.

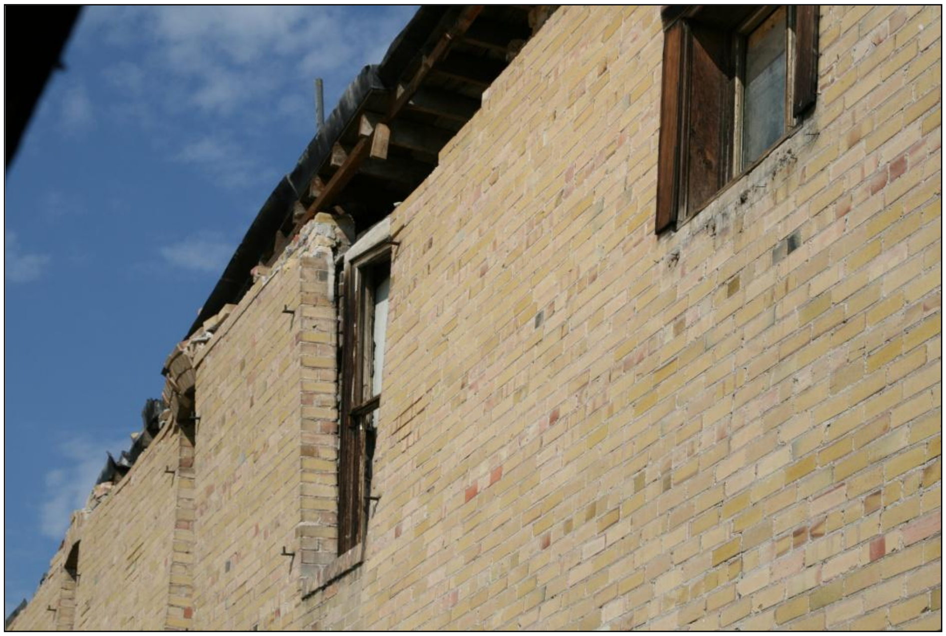

Figure 147. Close-up of out-of-plane parts of the eastern wall of the Nevada Hotel.

Figure 148. Southeast upper corner of the Nevada Hotel. The corner is badly cracked and is breaking up.

Figure 149. Collapsed western wall of the Nevada Hotel. Concrete block columns can be seen that extended up from the first story ceiling level half way up the wall in the front and relatively higher in the back part of the wall, where the parapet was lower. Many of the bricks that have fallen on Murphy's Bar around the stovepipe are in order and seem to have fallen out as a toppled unit.

Old West Inn

The Old West Inn is located in the southern half of the historical district block, facing 6th Street. The building is a free-standing two-story building that suffered relatively minor to slightly moderate damage. The building is an unreinforced masonry building that is painted, which may help protect the mortar some from exposure. There was remarkably limited damage to this building given its proximity to other more damaged buildings. At the Old West Inn there was a 5- to 6-m section of the upper western wall that fell out, a small part of the front flower bed fell down, and there was some damage to a chimney on the roof.

Figure 150. Front of the Old West Inn. Rocks forming a front façade were knocked down.

Figure 151. Failure of an upper section of the western wall of the Old West Inn. Most of the bricks fell outwards.

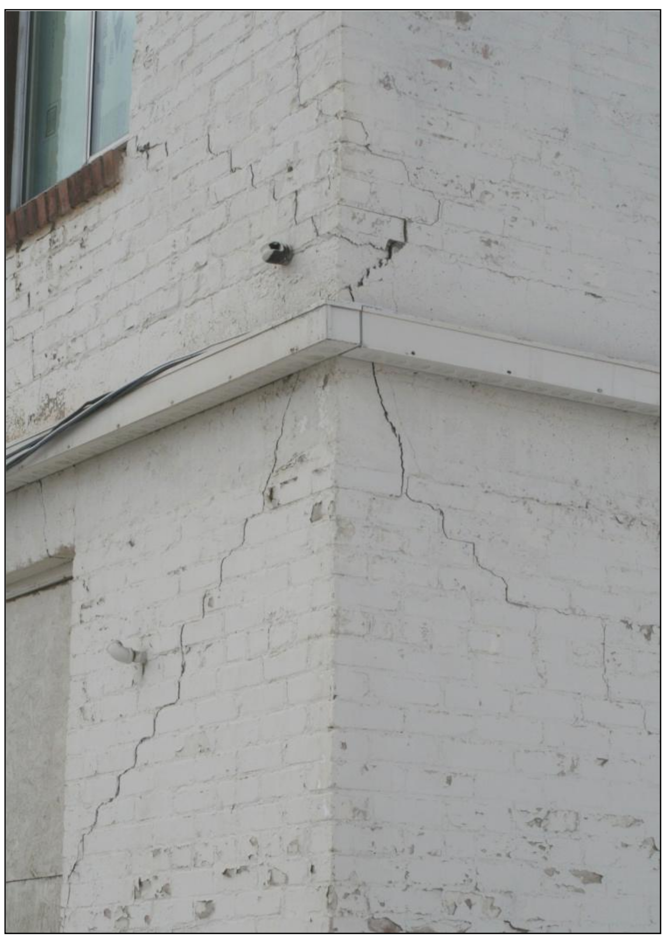

Figure 152. Cracked northwest corner of the Old West Inn.

Figure 153. Contrast between the limited damage to the two-story Old West Inn (to the right) and the shell of the collapsed San Marin Hotel (next to the red building on the left). The view is to the northeast.

Quilici and Sons Mercantile

Quilici and Sons Mercantile is an unreinforced masonry building built in 1901 that lies between the Bullshead Saloon and the Capitol Club buildings. The building is long, extending the full width of the block and has a higher rear roof than the front of the building, and a small standing skylight in the middle of the roof. Mortar exposed to weather on the top of the building had decayed badly and may have been particularly susceptible to dismemberment during shaking.

The store front suffered parapet damage, shaking, and fallen brick damage to a couple of roof and ceiling joist connections near the front northeast corner of the building. Bricks were shaken from the upper parts of the side walls of the building. The back wall was badly damaged with a collapsed parapet and sections of the wall, and major cracking of what remained standing.

Figure 154. Failed parapet at the front of Quilici and Sons Mercantile.

Figure 155. Fallen and delaminated bricks from the front parapet.

Figure 156. The front corner of the upper part of the front of the Quilici and Sons Mercantile is leaning outwards in a threatening way, despite the cross-course bricks on the end. There is a concentration of shaking damage at the corner of these two buildings.

Figures 157a. Fallen bricks from the front of the mercantile and the Bullshead Saloon in the front corner of the store. This corner is where some of the roof and ceiling joist connections failed.

Figure 157b. Close-up of figure 167a.

Figure 158. View to the north (front) of the Quilici and Sons Mercantile showing failed parapet from the back.

Figure 159. Weather-worn mortar on the top of the mercantile. This weaker mortar may have contributed to some of the dismemberment damage to the back corner.

Figure 160. Rear of Quilici Market showing the façade breaking away from the building. Note eroded mortar.

Figure 161. Area where bricks have fallen out near the roof on a side wall. The mortar lies pulverized around the remaining bricks.

Figure 162. The Quilici and Sons Mercantile showing failed rear parapet, gable end, and wall. More bricks have fallen out of the western side of the back than the eastern side.

Figure 163. Damage to the southeastern corner of the store.

Figure 164. Interior of the Quilici and Sons Mercantile showing the temporary support where roof joists failed. This is directly below the corner shown in figure 157a and 157b. *Photo by Glen Palmer*.

San Marin Hotel

The San Marin Hotel, built in 1902, was a vacant, run-down, two-story unreinforced masonry building that totally collapsed during the Wells earthquake. Only the front, two remnants from the back wall, and part of the wall near the Eagle Club remain standing, and these are badly cracked and damaged. The building had a second story floor and a roof, but appeared to lack any interior walls or bracing. The eastern side of the building is supported by being buttressed by the Eagle Club, but the western wall was free-standing next to an empty lot. The back wall had partly collapsed prior to the earthquake.

Figure 165. The San Marin Hotel before the earthquake. *Photograph by ExploreNevada.com.*

Figure 166. Remaining front of the San Marin Hotel after the earthquake.

During the Wells earthquake, the western wall of the San Marin Hotel appears to have nearly fallen out, nearly *en masse*, removing the western support for the second floor and roof and causing them to likewise fall to the west. The roof collapsed onto the second-story floor, and both fell onto the dismembered western wall. This tall, unsupported and unreinforced western wall would have experienced more drift near its top than near the bottom, causing the wall to bend. There may have been some horizontal torsion in this western wall as well because the front part was buttressed by the flag wall in its lower part, whereas the wall towards its rear was relatively unsupported.

Figure 167. Collapsed San Marin Hotel viewed from the back. The western wall has collapsed bringing down the second story and roof. Only the lower corners remain of the western wall. Displacement may have been relatively limited at the more rigid front of the building, which is buttressed by the concrete block wall. The opposite remaining corner is badly cracked.

An interesting aspect of this nearly totally collapsed building is that the front part of the building mostly stayed up. The first story and most of the second story of the front of this building remain standing, although they are badly cracked in places. This was a stronger part of the building, and perhaps significantly so. The front of the hotel was open with a door and windows. This created the need for a large beam that could carry the weight of the rest of the brick wall, so a fairly large concrete beam was used as a header. This beam was not only a strong, coherent mass, but it was buttressed in with a modern concrete-block wall (the flag wall) on one side and the Eagle Club building on the other.

Figure 168. Collapsed western wall of the San Marin Hotel. The wall has disintegrated into bricks, broken bricks, window frames, and bits of mortar. The roof lies on top of this wall and the second story floor on the right.

Figure 169. Remaining front of the second story of the San Marin Hotel. Note the concrete beam header for the front which was a relatively coherent part.

Figure 170. This shows a rear view of the San Marin Hotel.

Figure 171. The small room in the back of the San Marin Hotel appears to have been one of the few interior rooms in the hotel. This one of the few potentially survivable spaces in the collapsed building.

Figure 172. Part of the of the San Marin Hotel first floor not covered by the collapsed second floor and the roof, but completely covered with bricks. The front door (upper center of photo) has fallen bricks on both sides of it.

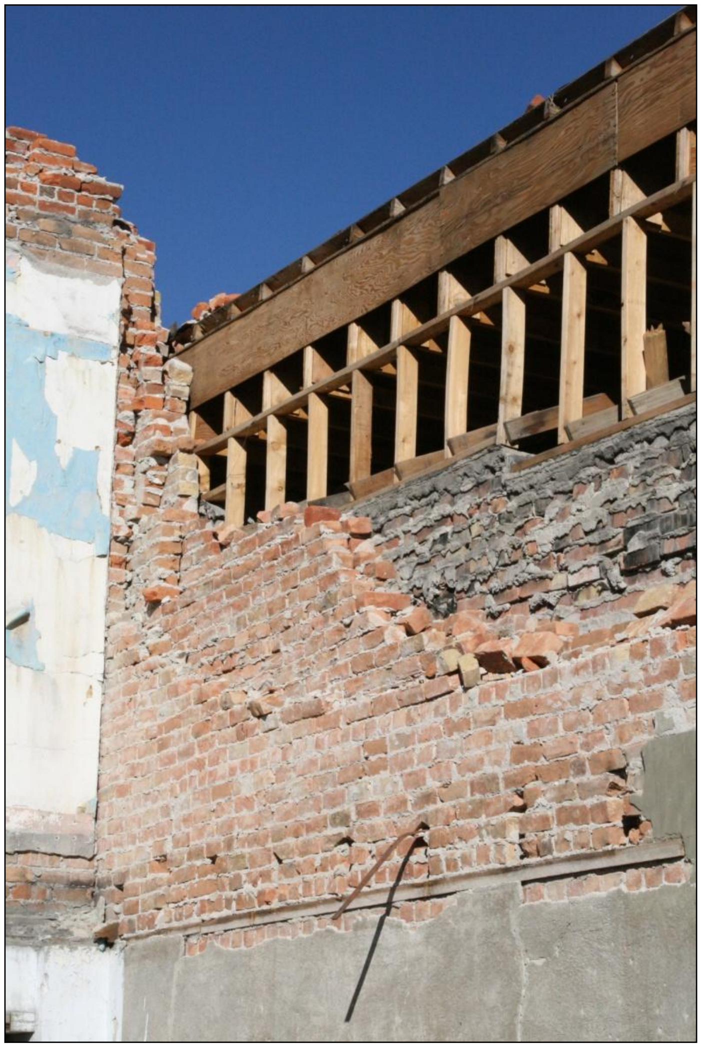

Figure 173. Part of the remaining eastern wall of the San Marin Hotel.

Wells Chalet

The Wells Chalet is a large, two-story building that housed a large dance hall on its second floor. It has several different structural elements to it, such as unreinforced brick walls with occasional infill of different kinds on the eastern wall above the roof line (e.g., concrete infill of a window), large concrete beams near the second-story ceiling line along the western and southern walls, and steel truss roof supports. Along the western, southern, and eastern sides there is a concrete bond beam at the top of the unreinforced wall that has two pieces of steel rebar in it. The steel trusses rest on the concrete beam on their western side and a concrete column on their eastern side.

The most spectacular damage to the Wells Chalet was the failure of the crowning bond beam along the western side of the building that crushed a car. The bond beam was on top of a short brick wall built on top of a concrete beam. This bond beam was thrown a significant distance to the west and hit the car, parked outboard of a sidewalk adjacent to the building. Because this is a short wall, the beam did not cantilever out but appeared to have been thrown to the west by a strong eastward pulse.

Figure 174. The Wells Chalet building, viewed towards the northeast showing the southern wall (center) and the shaded western wall (left). The building has unreinforced brick walls with large concrete beams at the top, partly to carry large steel trusses that hold up the roof over the second story dance floor. The Wells Chalet building appears to have shaken less than the adjacent Bullshead Saloon (seen farther down the block in the shadows with the fallen veneer) during the earthquake because the veneer on the west side of the chalet has not broken up and fallen away; this may be attributed to the stabilizing effect of the concrete beam, but note that nearly all of the windows are unbroken in the Wells Chalet as well.

Figure 175. Close-up of the second story concrete beam that apparently moved back-and-forth in an east-west direction. In several places between the windows, the wall is delaminating.

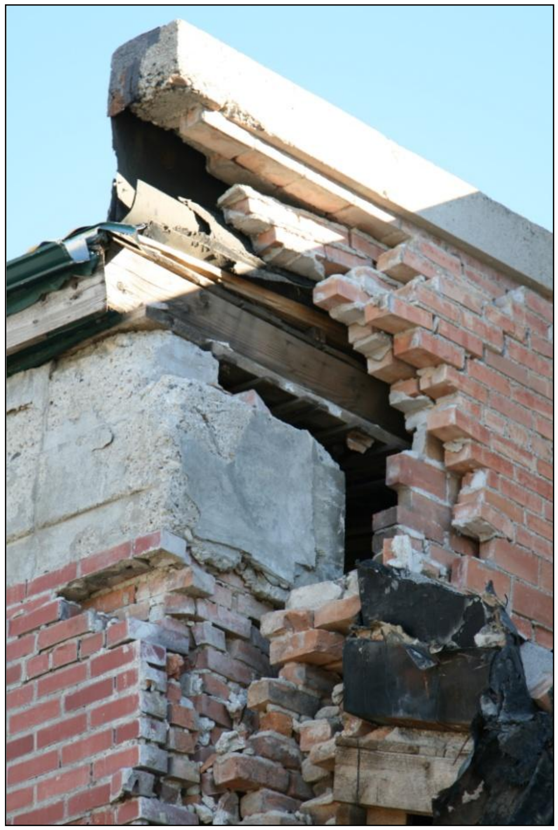

Figure 176. Close-up of where the concrete beam has pounded a hole into the eastern wall of the Wells Chalet and possibly the upper part of the parapet of the Quilici and Sons Mercantile (the tarred area in the lower right was part of the parapet). Note how the crowning bond beam is still in place and the failure did not peel from the top. The remaining surrounding bricks are bowed outwards slightly like they were pushed to the east.

Figure 177. Damage to the second-story southern wall of the Wells Chalet below the concrete beam. Interior picture showing cracking and some displaced bricks of the wall in the center of the picture.

Figure 178. Delaminating brick wall below the eastern end of the concrete beam and next to the window.

Figure 179. Southern part of the Bullshead Saloon (left) and northern part of the Wells Chalet (to right with the concrete beam near the top). The Wells Chalet appears to be a more rigid building (URM/concrete) versus the more flexible wood-framed Bullshead Saloon. The buttressed contact also apparently stiffened the edge of the Bullshead.

Figure 180. Broken bricks under and near the end of the concrete beam shown above.

Figure 181. Upper southwest corner of the Wells Chalet. A short brick wall sat on top of the concrete beam and was capped by a two-rebar reinforced bond beam. This bond beam was thrown off the western side of the building by the earthquake, clearing the sidewalk, and fell on the car, crushing it.

Figure 182. Car crushed by the crowning bond beam that fell from the Wells Chalet. The large bond beam cross section can be seen on the car.

Figure 183. Interior of the second floor of the Wells Chalet showing roofing, steel roof trusses, concrete columns and in the back corner is the chimney shown in figures 184 and 185.

Figure 184. Chimney inside the Wells Chalet that shows cracking consistent with buckling out in the middle (see figure 185).

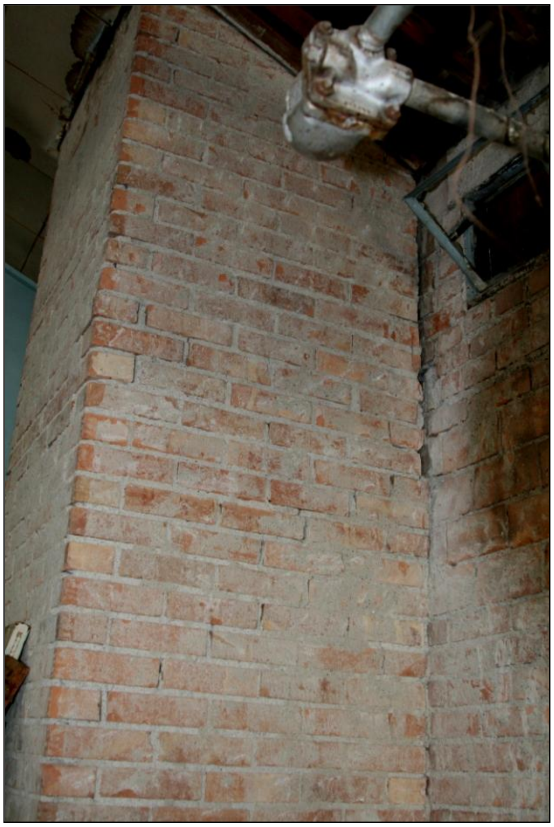

Figure 185. Chimney inside the Wells Chalet that shows cracking and buckling from shaking.