Nevada Bureau of Mines and Geology Special Publication 36

Damage to Residential Houses from the 2008 Wells, Nevada Earthquake

by

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2011

ABSTRACT

There are approximately 550 houses in the Wells, Nevada region that were built over the last century and they vary widely in construction types and maintenance. All but three of these houses survived the magnitude 6, 2008 Wells, Nevada earthquake structurally intact and were immediately inhabitable following the event. About 50 houses (the approximate number of yellow-tagged, restricted-use, homes) had some nonstructural damage, consisting mostly of chimney or stovepipe damage and cracking of finishes. No wood-framed or masonry houses were shifted off their foundations but several manufactured homes were knocked off their jacks or shifted on their support blocks. Nearly all of the houses in town had some cosmetic cracking in exterior and interior walls from the shaking, and had some displacement of or damage to contents.

Of the three structurally damaged houses, one was an older rock-walled house with wooden floors and roof and a rubble rock foundation. This house had failure of the upper part of a wall and a portion of the base of a wall that collapsed into the basement. This home was subsequently demolished and replaced with a manufactured house on a concrete foundation. The second was a manufactured home that was built partly on soil fill material. It shook violently, was knocked off its jack stands (a few of which punched through the floor) and the base of the home was wrenched. This house was subsequently removed and a new manufactured home was placed on a foundation at its former location. A third, approximately century-old railroad-tie home was damaged beyond repair, with most of the damage occurring at the connections with house additions. This house had to be demolished and was replaced with a manufactured home.

Nonstructural damage was widespread in both Wells and over the adjacent epicentral area to the northeast. In the near-field over the earthquake rupture, nearly every cabinet was emptied and all objects that could be toppled or fall from walls did so. In Wells, immediately south of the earthquake rupture, there was commonly a preferred direction to the shaking where two parallel walls of the house had nonstructural content damage, but along the other two walls items stayed put. In the City of Wells, about 60 chimneys were damaged, which is about 10% to 15% of the total chimneys in town. Most of these damaged chimneys were on residential buildings and were built of unreinforced masonry construction.

The total damage to all residential homes will never be known because there likely remains hidden damage. For example, some residents report that since the earthquake their homes sway much more in the wind and they are finding that framing connections have been weakened or broken from the shaking. But overall, good modern construction seems to have survived the adjacent magnitude 6 earthquake well, and 99% of the houses in the Wells area had no noticeable structural damage. This is potentially good news because similar magnitude earthquakes can occur anywhere in Nevada. The unfortunate qualifying fact is that larger earthquakes will occur in Nevada, so homes will be subjected to larger earthquake shaking forces than what occurred in the Wells area in 2008.

INTRODUCTION

On February 21, 2008, a magnitude 6 earthquake nucleated just north of Wells, Nevada and propagated towards town. Shaking in Wells is reported to have lasted for 40 seconds and included some violent pulses. This event shook several hundred houses in and about town and served as a real-time, real-scale shake test for home construction in the region.

The City of Wells has grown for over a century and has buildings of all ages and types of construction. The dominant types of home construction are wood-framed, brick, concrete masonry unit, and manufactured homes. A significant portion of the older wood-framed residential construction was done with railroad tie and /or wood plank construction. More recent construction has been guided by the 1997 Uniform Building Code and its seismic provisions, which had been adopted by the city several years prior to the earthquake.

This report includes observations made during post-earthquake reconnaissance of the area, and numerous interviews with personnel from the City of Wells, Wells citizens, engineers, and other professionals. The paper focuses on and describes structural and nonstructural damage to residential homes from the earthquake.

WOOD AND MASONRY HOUSES

The two most common types of house construction within Wells are wood-framed construction and brick construction. Wood-framed houses were built from the late 1800s to recent years. Brick houses were built in the early to mid-1900s. Because of the railroad origin and prevalence in the town, several houses were made out of railroad ties and other salvaged wood (figure 1). The ties were placed either horizontally or vertically to construct walls.

Figure 1. Railroad-tie house construction. The ties were placed vertically to make up the walls of this garage. This house was in the Modified Mercalli Intensity VII area but barely had a crack in it from the earthquake.

One well-built, single-story railroad-tie house appeared to have suffered nothing more than minor cracking from the shaking (figure 1). A two-story house constructed with vertically placed 2”x 8” wood planks for the walls reportedly had much larger shaking motions than other homes, but the house itself experienced little damage except for considerable plaster cracking. These examples indicate that these older wood construction homes can survive earthquake ground motion if they are built well.

Two other older built houses in the Wells area were destroyed by the earthquake, one with rock walls and a rubble-rock foundation and one that had a railroad-tie construction core house and several additions attached through time. These two houses illustrate the serious consequences resulting from older construction methods that do not meet current lateral force resisting requirements and have weak structural features, such as the lack of adequate connections between building members.

One of the severely damaged houses in Wells was a rock-walled house with a wooden floor and roof structure and a rubble-rock foundation (figure 2). One side wall was separated from the structure at the roof line and some rocks fell out (figure 3). Some large cracks formed around window frames and within the rock walls (figure 4). The most dramatic failure of the house from the earthquake was the collapse of part of a rubble-rock foundation that caused an approximately 4-m-long and 1.5-m-high section of the base of the rock wall to fall into the basement (figures 5, 6, and 7). This failure exposed interior wood boards which had dry rot and deterioration in places (figure 6). The rock house was subsequently torn down and removed and a manufactured home was installed on a new concrete foundation in its place.

Figure 2. Rock wall house that was damaged beyond repair. The red “unsafe to occupy” posting can be seen in the window.

Figure 3. Upper part of rock wall where blocks were dislodged at the roof line. *Photo by Glen Palmer*

Figure 4. Shaking crack formed where the window frame was separated from the rock cladding in the rock-veneered house. Note the window was not broken.

Figures 5 and 6. Figure 5 on the left shows an area where the rock house foundation collapsed sending rocks from the veneer into the basement. Figure 6 on the right shows a close-up view of the iron mesh used in the rock walls and some dry rot near the bottom of the wall.

Figure 7. Collapse of the rubble-rock foundation and bottom of the rock wall into the basement of the rock house. *Photo by Glen Palmer*

The other severely damaged home was a wood-framed composite house with a railroad-tie core and several additions put on through time. This house had cracked exterior walls, severe chimney damage, and severe damage and weather leakage at the connections with the additions. Conflicting stiffness of the older versus the newer construction could have caused the various portions of the home to impact each other during the earthquake. Thus, the composite nature of this house with apparent poor construction attaching the additions weakened this home. This house has been demolished and removed, and a new foundation has been poured, but a new house has not been put up on the site yet.

Several brick houses had severe cracking in different locations (e.g., figure 8), but none showed failure beyond the chimneys and their foundations remained intact. Some of these have been repaired by filling and putting epoxy in the cracks in the bricks, and none were considered total losses.

Cracked and damaged masonry basement foundation walls were observed at a couple of houses (Glen Palmer, 2010, written communication). This appeared to be further, new cracking of existing cracks. Neither home was considered a total loss.

Most of the homes of wood and masonry construction survived the earthquake with no apparent structural damage. This includes some unconventional railroad tie and wood plank house construction that occurs locally. The two destroyed houses had weak elements to them; one with a rubble-rock foundation and relatively weak rock walls and one with inadequate connections between different parts of the house.

DAMAGE TO MANUFACTURED HOMES

Several manufactured homes were knocked off their jacks or shifted on their support blocks by the shaking, although most manufactured houses in town remained on their supports. One manufactured home was severely damaged when the building shifted and fell off its jacks, twisted the frame, and fell onto the displaced support jacks, some that came up through the floor (figures 9, 10, 11). This home was removed and a new manufactured home on a concrete foundation was put in its place. In other cases, manufactured homes just collapsed on top of the prior support, settled onto the ground, or didn't fall but shifted on their blocks. In most cases, this shift was small or the manufactured home rode out the earthquake without any movement on their blocks.

In two cases, the factory-installed gas piping within the home broke, creating natural gas leaks. The residents smelled the gas leakage and turned the gas to their home off. The technician who fixed these pipes felt they were slightly undersized, putting some stress on the pipes that was exacerbated by movement during the earthquake.

Figure 8. Damaged brick house. Large X-shaking fractures emanate from the corners of the window extending to the corners of the house; the window is broken with a partial X-fracture as well. The fate of this house was still unknown, but similar brick houses with cracking damage have been repaired and continue to be occupied.

Figure 9. Manufactured home that was knocked off its jacks and destroyed. *Photo by Bonnie Stark*

Figure 10. View of the rear of the damaged manufactured home. *Photo by Bonnie Stark*

Figure 11. Support jack penetrating the floor after the home was knocked off its foundation. *Photo by Bonnie Stark*

In the resetting of the earthquake-displaced manufactured homes, and in several other cases, manufactured homes were being strapped in two directions on their supports to resist future shaking displacement and damage. This foundation strapping was not always done in the past, but is now required in the building codes to help avoid the problems discovered during this event.

NONSTRUCTURAL DAMAGE TO HOUSES

Nonstructural damage to houses from the earthquake mostly occurred in weaker or older homes, or to vulnerable elements, such as narrow, tall chimneys. The most common nonstructural house damage was to chimneys (described further below). Additionally, there were some cracked and broken windows, and cracks in interior and exterior walls. In a few cases electric lines, masts, and meters were damaged by falling bricks or shaking.

DAMAGE TO CHIMNEYS

Over 60 chimneys were damaged by the Wells earthquake, which was approximately 10% to 15% of the total number in town. Most of these damaged chimneys were at houses, but there were a few at commercial buildings. Damaged chimneys were broken at the roof line, shattered in place (figure 12), or toppled over onto the roof and/or the ground (figure 13). Falling chimneys and parapets posed some of the most serious safety threats from this earthquake event, but fortunately no one was injured by them. There was some damage to possessions from toppled chimneys however, such as to a car (figure 14). None of the damaged chimneys observed penetrated the adjacent roofs. Where chimneys had pulled away from walls or roofs there were some holes in houses that had to be patched to keep the weather out. In a couple cases, falling bricks from chimneys damaged electrical components requiring that the electric lines be disconnected by the power company.

Metal stove pipes generally faired pretty well, although a couple of these were damaged and some wood stoves were shifted sideways or forward from the shaking. In several cases stove pipes had been installed within brick chimneys, which may have stabilized some chimneys and helped prevent damage. This wasn't universally true, however, and a couple of these stove-pipe-lined chimneys still shed bricks from their tops. Some furnace and water heater exhaust pipes were misaligned from their ceiling connections and had to be realigned to prevent carbon monoxide and other gases from leaking into the houses.

Damaged chimneys were an immediate concern because the temperatures were cold, and there were winds from passing cold fronts. It was feared that someone might start a fire in a damaged stove or chimney to get warm, possibly leading to a larger threatening fire. The Wells Fire Department and Nevada Division of Forestry personnel worked with residents that needed to use their stoves, inspecting the stoves and chimneys inside the house, in the attic, and outside the house for damage. They were able to clear several stoves and chimneys for use within a day or so of the earthquake.

Emergency personnel from nearly all available agencies and companies began immediate recovery work by tearing down damaged chimneys and covering the resultant holes to keep the weather out and the heat in the homes. One engineer noted an unsafe practice of taking a chimney down to an intermediate level in the attics of houses where they were no longer supported by their roof connection creating a potentially even greater toppling hazard (figure 15).

It is recommended that free-standing chimneys be taken down to just above the ceiling line so that the tops of chimneys are supported at the ceiling level, and aren't left free-standing in the attic.

NONSTRUCTURAL DAMAGE TO BUILDING CONTENTS

Nearly every home and business in Wells had minor to substantial displacement and damage to at least some of its contents. A rough estimate on the average loss per home is about $1,000 worth of contents, with the actual value ranging from minor losses to a few thousand dollars. Common content losses included televisions, fish tanks, lamps, vases, dishes, glasses, cups, and pictures. Some of these losses were fairly easy for people to deal with and some items were irreplaceable. Most residents had not given any attention to securing possessions or home contents prior to the earthquake event.

One Wells earthquake incident serves as a pointed example of the importance of relocating heavy objects that might fall on residents during an earthquake. A young mother with a newborn baby had returned to Wells to stay with her parents just before the February 2008 earthquake. The family had set up a temporary makeshift nursery in a small entertainment room, with the crib situated directly beneath a large television set on an overhanging stand. The three-week-old infant had been sleeping in this crib up to two nights before the earthquake, but fortunately the mother and child were temporarily away on a trip when the earthquake occurred. Figure 16 shows how the television was displaced and thrown into the crib during the earthquake. Given the size of the television, the infant would undoubtedly have been crushed if she had been present in the crib in the early morning hours when the earthquake occurred. This incident serves as a lesson that even in an area where earthquakes have a low probability of occurrence, the severe consequences of such an earthquake event must be considered. Cribs, beds, desks, tables, and places where inhabitants spend much time should be placed in areas that do not have large or heavy overhead objects that could fall during an earthquake, or those threats should be relocated.

Figure 12. Shattered and fallen chimney from the Bargain Barn roof in old town; the chimney is disintegrating in place.

Figure 13. The fallen upper part of a chimney that broke near the roof line.

Figure 14. Car damaged by a fallen cinder-block chimney.

Figure 15. The top of this broken chimney was removed but the portion above the ceiling in the attic was left free-standing, creating a possible toppling hazard from further shaking during aftershocks. *Photo by Glen Palmer*

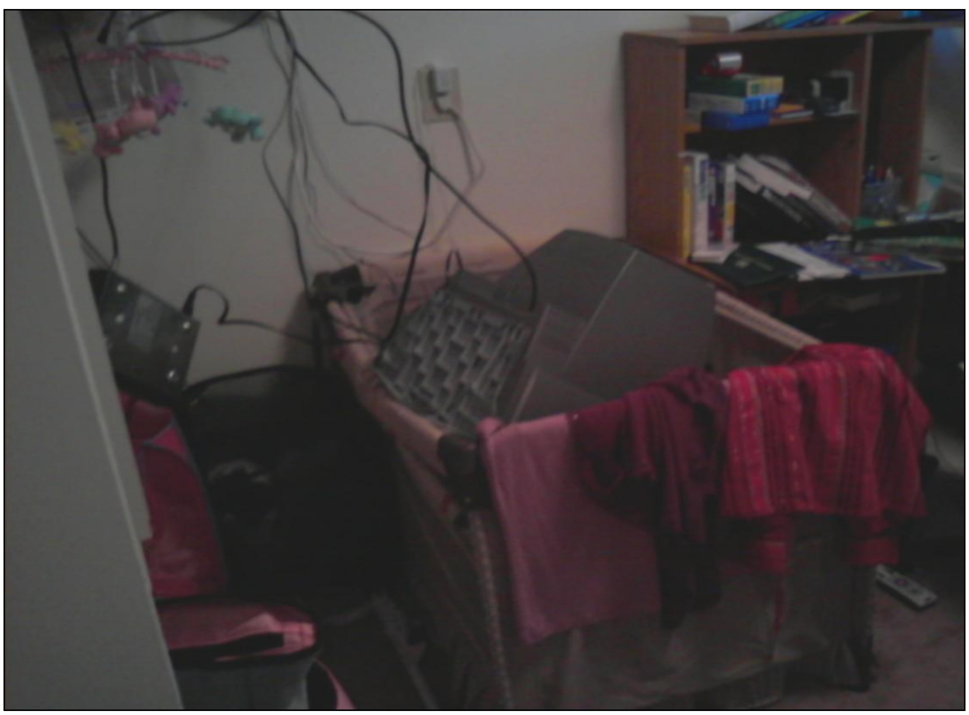

Figure 16. A television fell into a crib in a temporary nursery. A three-week-old girl was in the crib a couple nights before the earthquake, but not at the time of the event. Even though the probability of an earthquake occurring was not high before the event, similar potentially deadly hazards should be addressed everywhere in Nevada. *Photo by resident*

Although nonstructural content damage was widespread in Wells, in most cases it was limited and not extensive throughout the houses or buildings. In Wells, there seemed to be a preferred direction to the shaking that caused dislocation and damage of contents, affecting one set of parallel walls and not the other. In the homes that were directly over the earthquake rupture to the north in Town Creek Flat, nonstructural displacement and damage was more intense, with nearly every cabinet opened and emptied of its contents along all walls. Most nonstructural damage occurred to loose objects or those that were horizontally unstable (figures 17 and 18).

Figure 17. Cabinet doors were opened and contents thrown out by the earthquake. *Photo by Bonnie Stark*

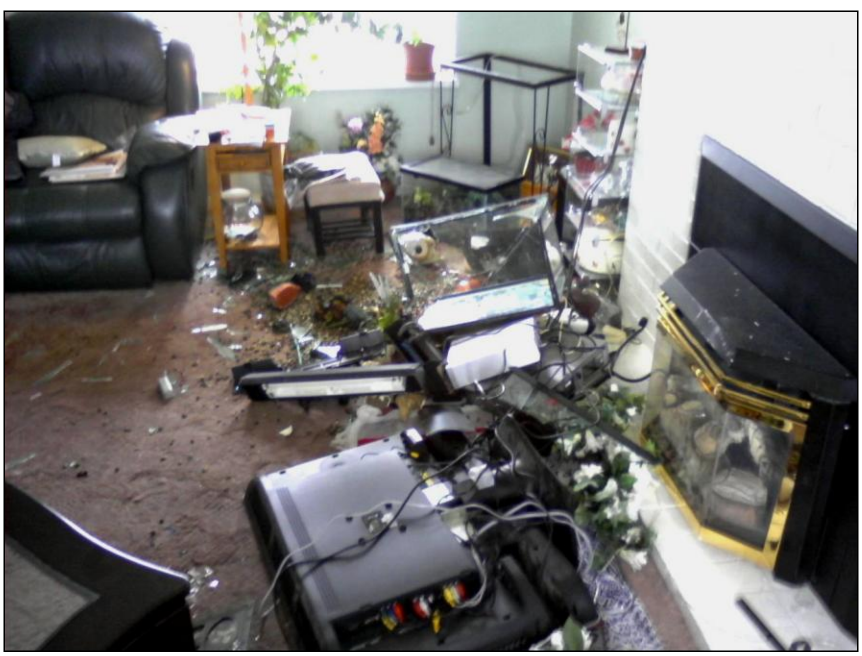

Figure 18. Nonstructural damage in a home. *Photo by resident*

SURVIVAL OF MODERN HOMES

Modern homes appeared to survive the earthquake without any visible structural damage (e.g., figures 19 and 20), although there were some shaking cracks and nonstructural content damage. These are mostly wood-frame houses, some with brick or other veneer finishes. The 1997 Uniform Building Code had been enforced in Wells for several years prior to the earthquake, which added seismic resistance to newer homes and likely contributed to their surviving the event with their structural integrity for the most part intact.

Figures 19 and 20. (above and below) Modern homes and chimneys survived the earthquake shaking with no visible structural damage.

The fact that most modern construction homes did not have structural damage from the Wells earthquake is a testament to the effectiveness of strong building codes in promoting overall seismic survivability of residential buildings. Nevada is earthquake country and without warning, buildings can be subjected to severe shaking, even stronger and longer than what occurred during this 2008 event. To continue having overall good results with houses following earthquakes, seismically resistant design and quality construction of homes and buildings needs to continue and possibly be enhanced in some areas. In addition, some seismic strengthening of pre-existing weaker buildings should occur. The 2008 Wells earthquake should serve as a wake-up call to other county and municipal governments that the adoption and enforcement of sound building codes is an effective way to achieve similar results.

CONCLUSIONS

Three houses were severely damaged from the 2008 earthquake and had to be replaced, but 99% of the residential homes in Wells survived the earthquake with minimal visible structural damage, and could be immediately occupied following the event. There were about 450 houses within the City of Wells and approximately 100 additional homes and buildings in surrounding Elko County that were severely shaken. About 50 houses had some serious nonstructural damage and were yellow tagged for limited occupancy. Although several manufactured homes shifted on their jacks or support blocks, no wood-framed or masonry houses were shaken off their foundations. There was evidence of severe shaking in virtually all local homes, mostly consisting of cracks in wall board and bricks, and widespread nonstructural content damage.

One of the three damaged homes was an older wood-frame house and the second was a rock-bearing-wall house. The earthquake damage and condition of these two structures was deemed "un-repairable". These structures had damaged walls at the roof connections, failure of a rubble-rock-wall foundation, failure of the base of a rock wall, severe interior and exterior cracking, and failure of connections of additions to a house. The third damaged home, a manufactured home, fell off its jack stands, wrenching its frame and punching some of the jack stands through the floor; a cut-and-fill pad on which the home had been placed likely made shaking more severe. All three of these houses have been removed or demolished and have been replaced with new manufactured houses on concrete foundations.

There are three major lessons to be learned from the damage to residential homes due to the 2008 Wells earthquake:

Lesson 1. Low probabilities may have high-consequence results. Most Nevada residences and buildings are filled with families and people, rendering them "high-value" in all situations and warranting some preparedness actions. Vigorous earthquake preparedness and safety should be practiced throughout Nevada and other earthquake-prone areas.

Lesson 2. Although older homes survived better than expected, homes constructed to meet the newer building code criteria did significantly better overall than those constructed with older, less stringent standards. This supports the fact that adherence to modern building codes protects people and their property from earthquakes.

Lesson 3. One consistent failure found where seismic shaking was the strongest was damage to unreinforced masonry projections, particularly chimneys. These unreinforced projections, whether they are above the roof or hidden within attic spaces, should be reinforced or removed whenever the opportunity presents itself.

ACKNOWLEDGMENTS

Special thanks are given to Glen Palmer, of Palmer Engineering in Utah and to Alan Bennett of the Reno Building Department for reviewing and making numerous suggested improvements to this manuscript. Mr. Palmer also suggested additional lessons and offered other observations on affected houses in Wells, and the manuscript is distinctly better because of his input and additions. Thanks also to D.D. LaPointe who made several editorial improvements in text. Thank you also to several Wells residents who offered access to their homes for inspection during physically and emotionally difficult times.