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DOWNTIME DATA ON RESIDENTIAL BUILDINGS AFTER THE NORTHRIDGE AND LOMA PRIETA EARTHQUAKES

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ABSTRACT

Building department permit data from the 1989 Loma Prieta earthquake and the 1994 Northridge earthquake was used to evaluate the period of time between the event and the certificate of occupancy. Overall, the repair of damaged multifamily residential buildings required two years and building replacement required four years. Downtime modeling can more accurately represent losses when construction repair times are supplemented by estimates of the time gap between closure and repair. This paper will include data developed for Pacific Earthquake Engineering (PEER) Center's Performance Based Earthquake Engineering (PBEE) methodology.

Introduction

When buildings or infrastructure are damaged in a natural or manmade disaster, there is a period of time needed to inspect the facility, ascertain the degree of structural, nonstructural, or hazardous materials damage, make decisions to close, repair, or re-open the facility. Estimating the downtime between damage and re-occupancy is key to understanding the economic impacts of a disaster. Loss estimating models typically use construction time needed for repair to represent downtime. However, experience in recent disasters suggests that the time to repair is only one component of downtime. Often there is a large gap between the damage and closure of a facility and the beginning of construction for repairs. Estimating the mobilization component combined with the construction time provides a more accurate representation of the real time economic losses associated with facility closure.

A preliminary empirical study of downtime as a measure of time to occupancy for residential buildings was included in a series of papers published by the Association of Bay Area Governments (ABAG 2000). Comerio defined downtime and published a case study of downtime at Stanford University after the Loma Prieta earthquake (Comerio 2006). Given that the majority of losses in earthquakes have been outside the United States in the past 20 years there is little empirical downtime experience to calibrate loss models. The best data available is for wood-frame

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residential buildings. We expanded upon the 2000 ABAG study by adding information from additional sources to refine the understanding of each building's post-earthquake status—whether it was repaired, demolished or rebuilt. This allowed us to conduct a statistical analysis on building department data from the following Northridge-affected areas: the City of Los Angeles, unincorporated Los Angeles County and the City of Santa Monica. Additionally, we used data from the following Loma Prieta-affected areas: the City and County of San Francisco, the City of Hollister and the City of Watsonville. Overall, the data used in our PEER study is a combination of information acquired from local and county governments (particularly building departments) by ABAG subsequent to the Loma Prieta and Northridge earthquakes as well as census and county Assessor's data as of 2006 for the same properties.

Building Tagging and Status after Earthquakes

After an earthquake, the local building department conducts a windshield survey of damaged areas and assigns a green, yellow or red tag to each building inspected. Green-tagged buildings are considered safe to enter—with no structural damage. Yellow-tagged buildings are thought to be unsafe , need additional engineering review and so entry is allowed only for short periods of time. Red-tagged buildings are considered unsafe and no entry is allowed. Owners typically will hire engineers to review the status of yellow- and red-tagged buildings and the tag can change based on additional engineering evaluations submitted to the city. This means that owners need time to evaluate what might be required by local government and to decide on a course of action—whether to repair or demolish.

We made informed decisions about the fates of buildings (repaired, demolished and/or rebuilt) damaged by the Northridge and Loma Prieta earthquakes using a combination of ABAG Data and Assessor Data supplemented with anecdotal knowledge of local conditions. The application of data in concert with information from independent sources results in stronger conclusions than possible if these sources were used separately. In particular, the permitting information and field inspection data were the most useful sources of information from the ABAG Data. The Assessor Data provided updated (2006) building characteristics (such as the construction year) and financial information (the most reliable information from the Assessor) such as the ratio of improvements to land value (the multiplier to land value which results in the value of built improvements to the property) and the most recent sales date and price. Individuals with extensive inspection experience provided anecdotal knowledge based on familiarity with the characteristics of the buildings (*e.g.* single family wood frame buildings likely would be repaired), the general degree of damage sustained in the different locations and the general approach of local authorities (*e.g.* Watsonville encouraged rapid repairs through permitting and financial incentives).

We assigned 84% of the properties a status of Repaired, Demolished or Demolished-Rebuilt based on evidence available in the data. The remaining properties had missing or inconclusive data which was supplemented with anecdotal information in order to be assigned a status. A summary of these results is in Table 1.

Statistical Analysis

Once the buildings were assigned a status (*i.e.* Repaired, Demolished and/or Demolished-Rebuilt) the timing and occupancy type information was summarized as a function of tag color (red or yellow), and relevant earthquake and location. Single Family is defined as one dwelling unit and Multi Family is defined as two or more dwelling units. The number of dwelling units is provided by the local building department or city authorities. The time to repair is the number of months between the earthquake and the "work completion" date provided by the local authorities for those buildings determined to have been repaired. Time to rebuild is the number of months between the earthquake and the "work completion" date provided by local authorities or July 1 of the year built from the Assessor's Data for those buildings determined to have been demolished and subsequently rebuilt. See Table 2 for a summary of results.

While the building characteristics were fairly complete, there were problems with the time to occupancy information. In fact, while 67% of the rebuilt properties have timing information, only 47% of the repaired properties have timing information. In general, the red-tagged population had a higher percentage of properties with timing information. This is possibly because the higher levels of damage sustained by these properties required the local authorities to be more vigilant over the repair and rebuilding processes. Furthermore, the lighter damage sustained by yellow-tagged properties may have compelled building owners to proceed with repairs without applying for work permits (and so building departments would have limited or no documentation of the timing of the work).

The two categories with the least amount of available timing data are the yellow-tagged Los Angeles buildings and the yellow-tagged San Francisco buildings. These Los Angeles buildings (representing 38% of the total population) only had timing information for 49% of the repaired or rebuilt buildings while these San Francisco buildings (representing 15% of the total population) only had timing information for 2% of the repaired or rebuilt buildings (and these were only for rebuilt buildings). If these two categories are excluded, 65% of the repaired and rebuilt properties of the other locations had information that suggest a time to occupancy. The majority of these (54%) are the repaired properties. In this breakdown 73% of the rebuilt properties have timing information while 64% of the repaired properties have timing information.

Additionally, 9% of the buildings were demolished and rebuilt and the remainder (3%) were demolished but not rebuilt. This methodology for determining a building's post-earthquake status (as described earlier) may have been somewhat biased toward repair, but it follows logically that most owners would prefer to repair than invest in demolition and rebuilding (particularly for the low-rise wood frame structures that dominate the population of buildings studied here). Furthermore, the population is almost evenly divided between red-tagged and yellow-tagged buildings. The majority of buildings (71%) are Multi Family and the predominant building type, consisting of 21% of the total, are 1-3 story Wood frame Multi-family buildings constructed after 1940. The overall mean time to occupancy was 21 months (1.8 years), the mean time to occupancy for repaired buildings was 19 months (1.6 years) and the mean time to occupancy for demolished and rebuilt buildings was 39 months (3.3 years).

Figures 1 and 2 respectively show the "mean months to repair" and the "mean months to rebuild" for housing damaged in the Northridge earthquake. In Figure 1, the vertical bars (blue = all repaired, yellow = single family housing, green = multifamily housing) show the number of months to repair, as indicated on the left axis for the City of Los Angeles red- and yellow-tagged buildings, unincorporated areas, and the City of Santa Monica red- and yellow-tagged buildings. It is clear that except in the unincorporated areas, a 24 month repair time is common. The purple horizontal line indicates the number of buildings in each category, as marked on the right axis. This demonstrates that the majority of the buildings are in the City of Los Angeles red and yellow-tagged categories. Similarly, in Figure 2, the mean months to rebuild are indicated by the vertical bars (purple = all demolished and rebuilt, pink = single family demolished and rebuilt, blue = multifamily demolished and rebuilt). In this case, 48 months was the rebuilding time in the Los Angeles red-tagged category which has the majority of buildings. The smaller number of yellow tagged buildings in Los Angeles took less time to rebuild. Other areas had very small numbers of buildings, but these all took between 36 and 48 months to repair.

Conclusion

This analysis focuses on time to occupancy measures as a function of tag color, building type and Single Family versus Multi family structures—one measure of building size/building use. These variables were used as they are the most relevant for residential buildings, they have consistent and recognized definitions among interested parties (such as building authorities, construction professionals, owners and academics) and the data is available. In addition to the building-specific factors which affect time to occupancy mentioned in the introduction, the amount of structural damage, earthquake intensity and geographic location (including proximity to the epicenter and proximity to natural and artificial structures of with a range of structural integrities) also affect the time to occupancy for a building. Finally, the mean times to occupancy for repaired buildings of almost 2 years and for demolished and rebuilt buildings of almost 3.5 years have significant implications for the post-earthquake strategies of governments, builders and owners. Notably, this population consists almost entirely of low-rise wood-frame structures. The time to occupancy for larger and more complex buildings could easily exceed these figures.

Data Summary (Tables and Charts)

The population consists of approximately 4900 residential buildings of which 74% were damaged by the Northridge earthquake. As this is almost 3 times the building population damaged by Loma Prieta, the Northridge results heavily color the overall statistics. The vast majority (88%) of the buildings is assumed to have been repaired and this proportion is consistent across several arrangements of the data such as by earthquake, tag color or location.

Table 1. Estimated Status of Red- and Yellow-Tagged Residential Buildings Damaged by the Loma Prieta and Northridge Earthquakes.

	Number of Buildings			
	Repaired	**Demolished**	**Demo/Rebuilt**	**Total**
Loma Prieta , October 17, 1989				
San Francisco				
Red-Tagged	178	10	28	216
Yellow-Tagged	738	2	13	753
Hollister	84	0	5	89
Watsonville	212	11	25	248
Loma Prieta Total	**1212**	**23**	**71**	**1306**
Northridge, January 17, 1994				
Los Angeles				
Red-Tagged	1044	41	215	1300
Yellow-Tagged	1703	55	97	1855
Los Angeles County (Unincorporated)				
Red-Tagged	187	21	52	260
Yellow-Tagged	126	0	0	126
Santa Monica				
Red-Tagged	13	6	8	27
Yellow-Tagged	54	3	6	63
Northridge Total	**3127**	**126**	**378**	**3631**
Total	**4339**	**149**	**449**	**4937**

Table 2. Number of Buildings by Occupancy Type and Mean Months to Occupancy.

	Number of Buildings by Occupancy Type		Mean Months to Occupancy		
	Single Family	Multi Family	Repaired Buildings	Rebuilt Buildings	All Buildings
Loma Prieta , October 17, 1989					
San Francisco					
Red-Tagged	43	172	7	46	13
Yellow-Tagged	194	559	**	**	**
Hollister	89	0	19	29	20
Watsonville	129	119	10	22	12
Northridge, January 17, 1994					
Los Angeles					
Red-Tagged	781	519	27	48	31
Yellow-Tagged	0	1855	25	30	25
Los Angeles County (Unincorporated)					
Red-Tagged	181	79	20	30	21
Yellow-Tagged	0	126	13	*	13
Santa Monica					
Red-Tagged	12	15	26	34	29
Yellow-Tagged	0	63	24	47	26

* There are no rebuilt properties.

** There is timing for the San Francisco Yellow-tagged buildings.

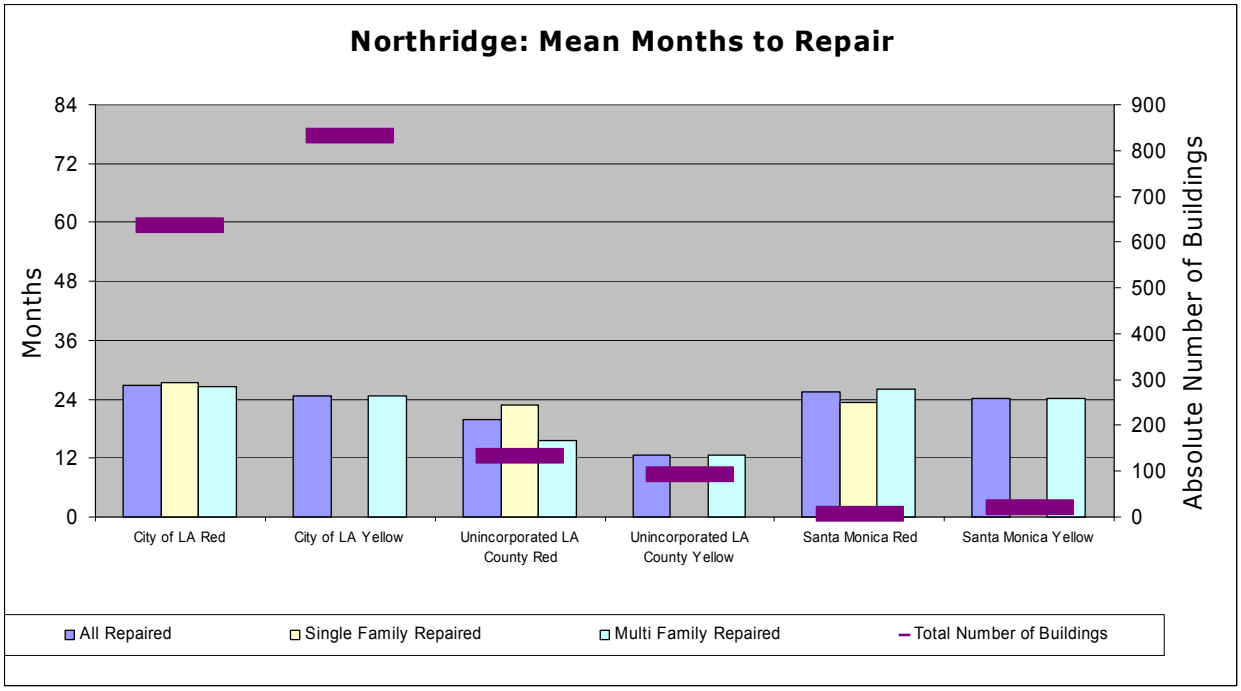

Figure 1. Northridge earthquake data on mean months to repair wood frame buildings.

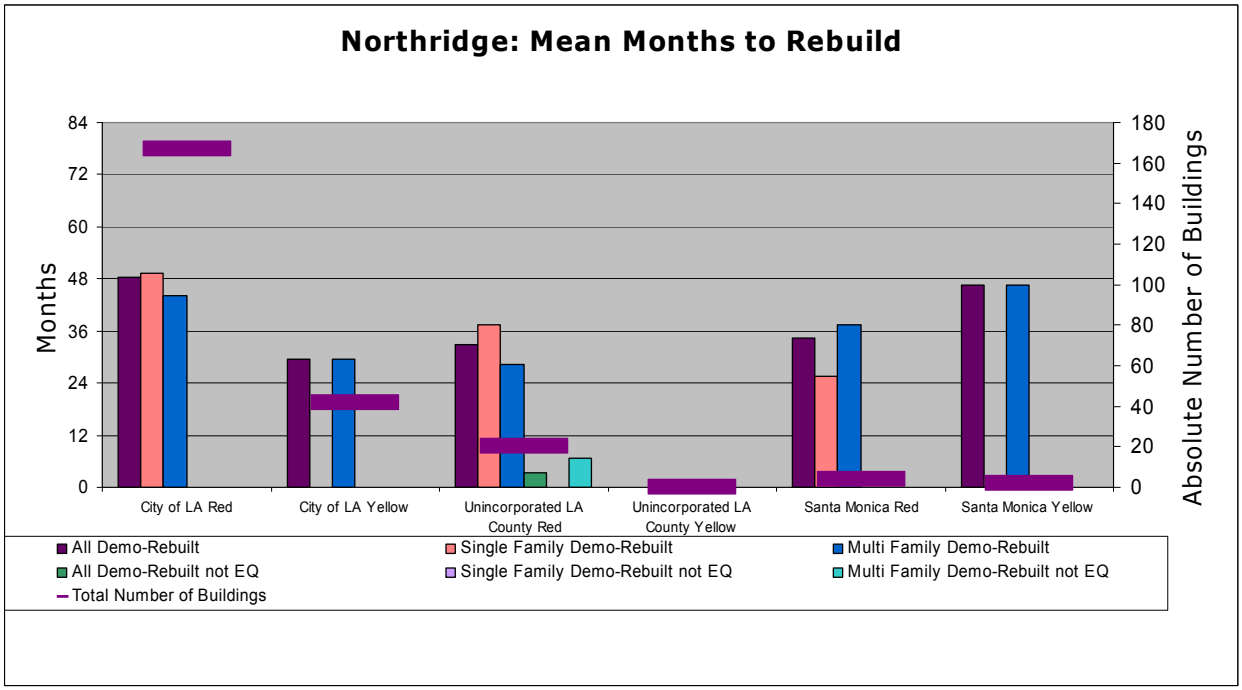

Figure 2. Northridge earthquake data on mean months to rebuild demolished wood frame buildings.

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