BUILDING DAMAGE SURVEY OF THE 2008 M8.0 WENCHUAN EARTHQUAKE AND ITS APPLICATION TO RISK MODELING

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ABSTRACT

The May 12, 2008, M8.0 Great Wenchuan earthquake caused more than 69,000 fatalities, and approximately 18,000 individuals are still missing. The quake ruptured more than 200*km* of the Longmenshan fault and affected more than 440,000 square kilometers. It damaged more than 24 million buildings and destroyed over 7 million houses. AIR Worldwide, a US based risk modeling company, dispatched a survey team to the disaster area to conduct a damage survey. The survey team travelled over 1,500*km* and amassed a database containing about 1,400 building damage assessments in five days. Assessments were based on direct observations by the survey team and interviews with local engineers and residents. Each assessment includes a record of the building's construction class, number of stories, occupancy, year built, damage ratio, latitude, and longitude. These assessments have been used to evaluate AIR's earlier real-time damage estimates, and comparison with model output confirms the superior performance of AIR's China earthquake model.

KEYWORDS: Wenchuan earthquake; damage survey; risk modeling

1. INTRODUCTION

The May 12, 2008, Great Wenchuan M8.0 earthquake was the deadliest in China since the 1976 M7.8 Tangshan event that claimed an estimated 242,000 lives. Its tremors were felt in most parts of China, as far as Shanghai, 1,700*km* away. In 2005, AIR Worldwide Corporation (AIR) developed its China earthquake model for estimating probabilistic property damage due to earthquake hazard in China. The model can be used for the design and development of insurance products and as a basis for government risk management. On May 13, one day after the earthquake, AIR issued loss estimates based on model simulation using available information on epicentral location, depth, magnitude, and rupture direction. The simulation indicated that total property losses, excluding damage from personal injury and infrastructure such as roads and dams, were in the range of RMB 75 – 200 billion (USD 10.7 – 28.5 billion), and likely to exceed RMB 140 billion (USD 20 billion). In order to verify these estimates and better understand building vulnerability in China, AIR dispatched a damage survey team to the disaster area to collect building damage data.

The survey team amassed a database of more than 1,400 assessments. Each assessment includes a record of the building's construction class, number of stories, occupancy, year built, damage ratio, latitude, and longitude. These assessments are used to evaluate AIR's earlier real-time damage estimates.

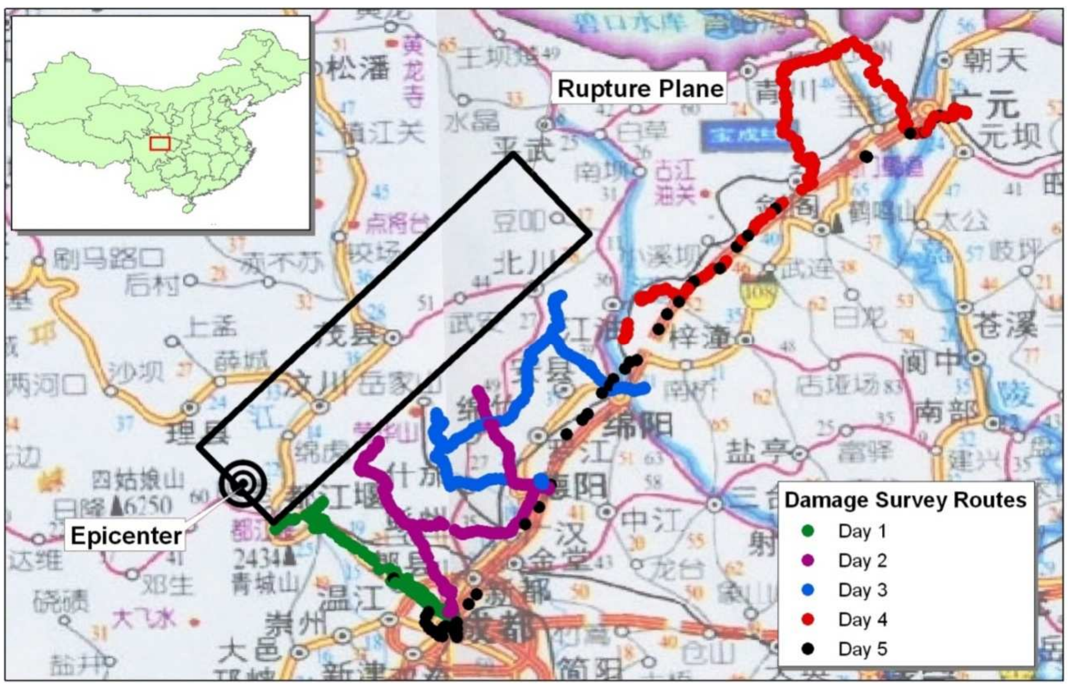


Figure 1: Survey route after the Great Wenchuan earthquake

2. SURVEY ROUTE AND DATA COLLECTED

During the 5-day reconnaissance, the survey team traveled over 1,500*km* to collect building damage data in the disaster areas. Figure 1 displays the route taken by the team during each day of the survey. The earthquake epicenter and the surface projection of the rupture plane are also presented in the figure. On day one, after meeting engineers in Chengdu, the team headed to Dujiangyan city, where underwriters from a local insurance company guided the team in surveying the city. The team later surveyed the town of Xuankou, about 6*km* away from the epicenter of the earthquake. On the morning of day two, the team visited the town of Longmenshan, and in the afternoon met underwriters in Deyang city, who escorted the team in surveying Mianzhu city and the town of Hanwang. Hanwang is densely populated with many large manufacturers, situated very close to the rupture, right next to the Longmenshan Mountains. With the help of the underwriters, the team was able to access restricted areas where debris had not yet been cleared. On day three, the team traveled to the towns of Hongbai and Leigu, and rested in Mianyang city, the second largest city in Sichuan province, next to Chengdu. On day four, the team approached Qingchuan, close to the border of Gansu province, which survived the main shock but was badly damaged by strong aftershocks days later. On the last day, the team made a brief tour in Guangyuan city and then headed back to Chengdu.

The team was equipped with a handheld PDA that was specially programmed to allow the surveyors to conveniently record and classify their observations. The device was also GPS capable and could automatically geocode the location of each assessment. The assessments were based on direct visual observations by the survey team along with interviews with local engineers and residents. A total of about 1,400 such damage assessments were collected. Each assessment includes a record of the building's construction class, number of stories, occupancy, year built, damage ratio, latitude, and longitude. Figure 2 illustrates the assessments amassed during this survey for mid-rise confined masonry (CM) buildings, one of the most common residential building construction types in urban areas of China. The locations where damage in CM buildings was assessed are shown as color-coded circles in the figure. The circles with darker color indicate more severe damage. The towns of Xuankou, Longmenshan, Hongbai, Hanwang and Beichuan were almost completely leveled. An example of a typical mid-rise CM building in urban areas is also shown in the bottom-right corner of this figure.

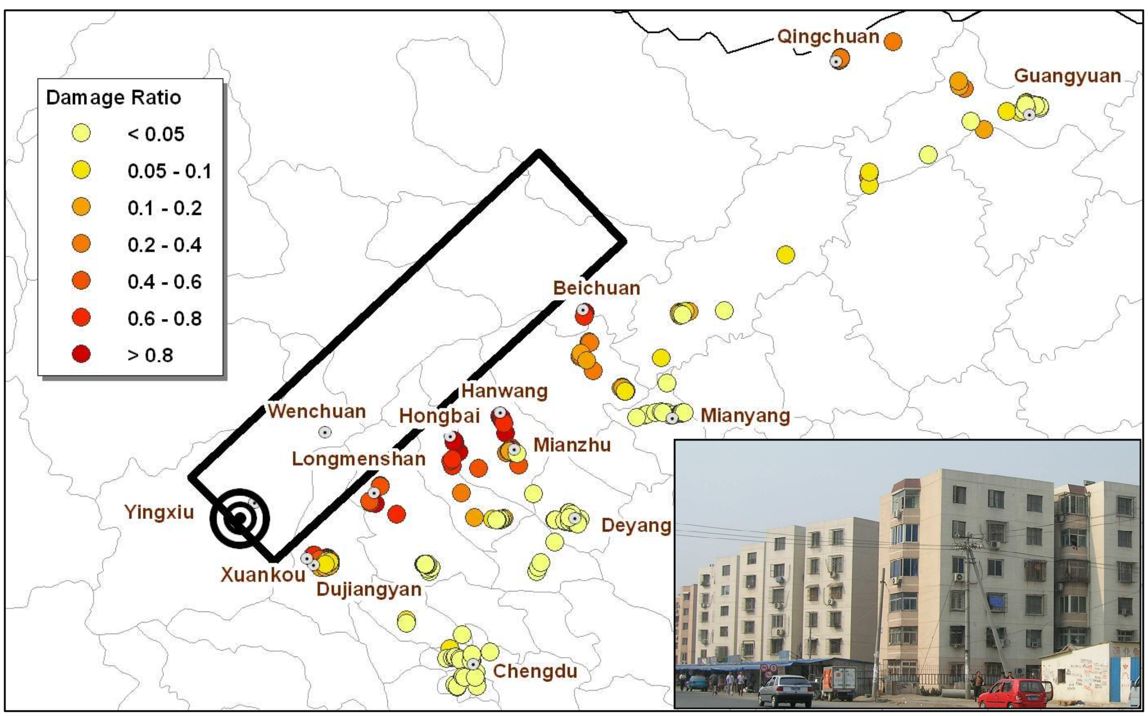
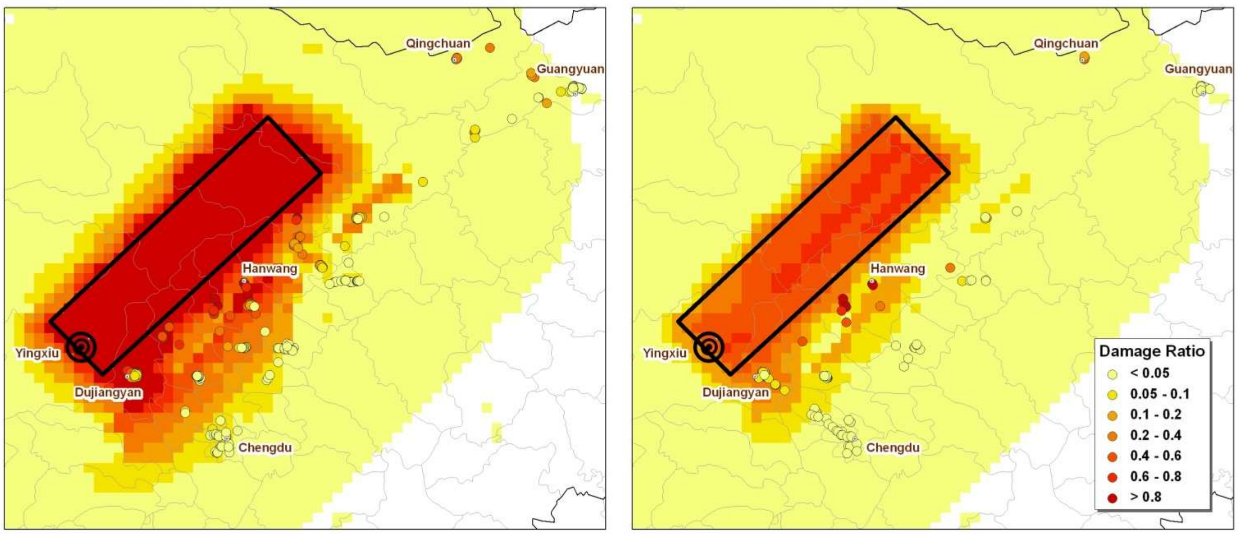


Figure 2: Spatial distribution and damage severity of assessments of Mid-rise CM buildings

3. APPLICATION OF DAMAGE ASSESSMENTS TO RISK MODELING

As mentioned above, the ultimate objective of this survey was to evaluate AIR's China earthquake model by comparing the field assessments with simulation results. Figure 3 shows comparisons between the damage survey observations and the simulation results from one of the five scenarios of the Great Wenchuan earthquake for which loss estimates were released by AIR on May 13, 2008. The mid-rise confined masonry (CM) and mid-rise reinforced concrete (RC) construction types were selected for this comparison study because they are the dominant residential building types in urban areas. The simulations were carried out by assuming that the buildings are hypothetically located at 5*km* resolution grid points throughout out the affected areas. The simulated damage is presented in background with color-coded damage severity, and the observed damage are scattered circles following the same color scheme. The model predicts almost complete damage for CM buildings and non-collapse severe damage in Yingxiu, Wenchuan, Beichuan and Hanwang, respectively. However, the model overestimates damage in Dujiangyan city and along this city to Chengdu because the simulation assumes uniform energy release across the entire rupture plane, while in reality the majority of the energy was released 15*km* northeast of the epicenter. This is probably the key reason Dujiangyan was spared from large-scale building collapse and that central Chengdu experienced only minimal damage. The model also underestimates damage near the Qingchuan city, which was affected by strong aftershocks. Otherwise, the model does reasonably well overall with very good agreement with the observed damage in Guangyuan city. Based on the above study, AIR is confident in its real-time loss estimates and in the general performance of its China earthquake model.



(a) (b)

Figure 3: Comparison of the observed (colored circles) and simulated damage (background color) for (a) mid-rise CM buildings and (b) mid-rise RC buildings

4. COMMENTS ON CURRENT CHINA BUILDING CODES

While there is no doubt that the large number of fatalities was caused by the collapse of many unreinforced masonry buildings and the poorly designed or older CM and RC buildings in rural areas, there is evidence that the buildings could have survived volatile shaking and that lives could be saved if the current building code were followed strictly. The two photos shown in Figure 4 were taken in the town of Hanwang, which is situated right next to the Longmenshan Mountains. Due to the city's close proximity to the fault rupture area, the city experienced intense ground shaking and was left in ruins after the earthquake. However, an office building of the Oriental Turbine Factory (Figure 4a) in this city not only survived the violent ground shaking, but also was able to partially resume its operation at the time of the survey. Judging by its appearance and height, the building is a RC shear wall type of structure built after 1990s. The ruined area shown in Figure 4b was where residential CM buildings once stood before the earthquake. Local residents told the surveyors that the buildings that were still standing were built in the 1990s while those that collapsed were built before and around 1980s. Apparently, the year built has a significant impact on the building vulnerability in China. However, this kind of damage was not a surprise to surveyors since the design intensity in this heavily damaged region is only 0.1*g*. Although the buildings that remained standing in Figure 4b did not collapse, they did experience severe damage which was apparent upon closer inspection. In conclusion, shear wall construction is very earthquake resistant, and the buildings that are still standing but damaged performed as expected by the building code. This is because the general objectives of the China building code state that a code-compliant building should experience zero to slight damage when subjected to frequent earthquakes, reparable damage when subjected to occasional earthquakes, and no collapse when subjected to rare earthquakes.

(a) (b)

Figure 4: Building damage in the area of the Oriental Turbine factory: (a) an office RC shear wall building with slight to moderate damage, (b) residential CM buildings collapsed (front) and severely damage (rear)

However, the surveyors believe that the current code needs some minor changes on the quantification of national seismic hazard and should clarify the assignment of important factors that would make public buildings like schools and hospitals more earthquake-resistant. Challenges remain in the enforcement of the building code during the reconstruction.

5. SUMMARY

After the May 12, 2008, Wenchuan earthquake, AIR dispatched a team of earthquake engineers to conduct a damage survey. The team traveled more than 1,500*km*, covering a wide range of the disaster area. With the help of new technology, about 1,400 damage assessments were collected in order to evaluate the performance of AIR's China earthquake model. Each assessment recorded the building's construction class, number of stories, occupancy, year built, damage ratio, latitude, and longitude. The study indicates a superior real-time loss estimate by AIR only one day after the earthquake. The engineers noted a significant improvement in building design and construction in China over the past few years and concluded that the current building code seems to work well if it is enforced. The building code needs minor corrections based on national seismic hazard assessment and clarification of the important factors for ensuring the seismic safety of public buildings. Challenges remain in the enforcement of the current building code during reconstruction.

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