RECONNAISSANCE OBSERVATION FROM MAY 12 CHINA EARTHQUAKE

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***ABSTRACT*:** At 14:28 local time on May 12, 2008, an M_S 8.0 earthquake struck the Sichuan Provinces, China. Millions of houses were damaged, leaving approximately 4.5 million people homeless. The government reported around 69,200 dead (18,000 still missing) and 374,000 injured. Right after the earthquake, civil engineers as well as search and rescue team from Taiwan headed for the affected region to provide immediate assistance. The author arrived at the affected region on May 27th to collect information such as structural and geotechnical damages as well as emergency response. Schools, hospitals, residential buildings, lifelines, landslides and bridges were surveyed and thousands of photos were taken to document the destructions this catastrophic earthquake had made. It is sincerely hoped that these reconnaissance information shared herein could help us to establish a better management system for hazard mitigation and to make a safer society in the future.

KEYWORDS: Earthquake, Reconnaissance, Hazard Mitigation

1. INTRODUCTION

A Magnitude (M_S) 8.0 earthquake struck Sichuan, China on May 12, 2008. Millions of houses were destroyed, leaving approximately 4.5 million people homeless. The total casualty is around 70,000 (18,000 still missing) plus 374,000 injured based on official statistics. The civil engineers of Taiwan immediately dispatched a team to the affected region on May 27th to conduct reconnaissance mission as well as to provide helpful information for seismic assessment, retrofitting and rebuild planning. We are fortunately to reach the damaged area nearest to the epicenter as early as possible to survey the schools, hospitals, residential buildings, landslides and bridges before they were demolished. Since then, several reconnaissance teams from Taiwan visited the destructive areas including Dujiangyan, Pongzhou, Xiaoyudong, Mianzhu, Zhiulong, Wudu, Hanwang, Bailu, Hsuanko, Xanzhao, Yingxiu (epicenter) and National Highway 213 (Lin, *et al.* 2008; Wu, *et al.* 2008; Lin and Chai, 2008). Thousands of photos were taken to document the damages made by this catastrophic earthquake. This information should help us in improving hazard mitigation management. We would also like to take this opportunity to express our deepest sympathies and condolences to the people of China and to the families of the victims for the loss of life and destruction caused by the earthquake. It is sincerely hoped that the reconnaissance information shared herein could help the affected communities in making a safer society in the future.

2. FIELD OBSERVATIONS ON BUILDING DAMAGES

The building damages in the affected region consist of schools, hospitals, commercial and residential buildings with three major structural types, i.e., reinforced concrete (RC), unreinforced masonry

(URM) and brick (masonry) buildings. The URM buildings are a unique structural system which consists of vulnerable brick columns, reinforced concrete beams, and precast concrete hollow floor planks with wire mesh (figure 1). Most of the public buildings are constructed using RC and URM systems, while most of the residential houses and school classrooms were made of URM with 4-7 stories and bricks with only one or two stories.

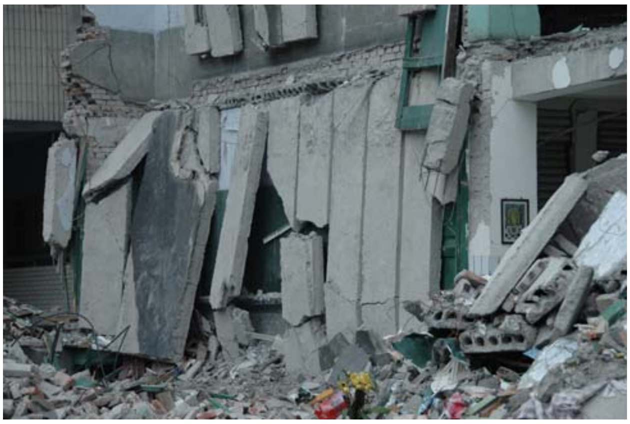

Fig. 1 The close-up view of the collapsed classroom

Fig. 2 The collapsed masonry classrooms

2.1 School, Commercial and Residential Buildings

A significant number of injures and casualties were associated with the total collapse of the school, commercial and residential buildings. Figures 2-6 show the collapsed buildings of elementary schools as well as failure and damage of commercial-residential buildings at Dujiangyan. Due to lack of ductile structural elements in the URM and masonry buildings to resist the seismic lateral force, the structural collapse and its consequences lead to human life losses and injuries are inevitable during a severe earthquake.

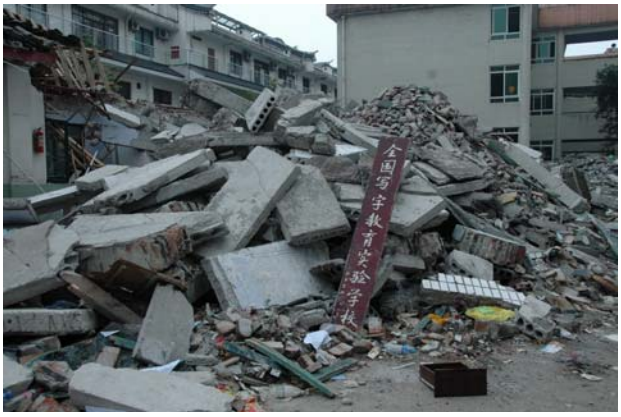

Fig. 3 The collapsed URM building in school

Fig. 4 The collapsed residential buildings (URM)

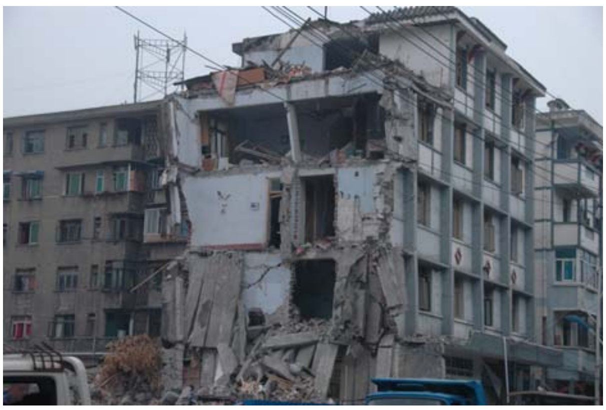

Fig. 5 The collapsed residential buildings (URM)

Fig. 6 The collapsed commercial buildings

Even the engineered RC buildings were experienced severe damage or collapse because of the strong shaking of the earthquake when near the epicenter; figures 7-10 show such damages in Hsuanko High School at Yingxiu (Wenchuan).

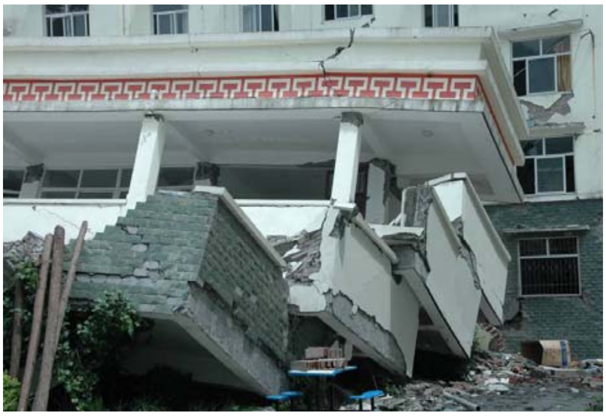

Fig. 7 The collapsed RC school building

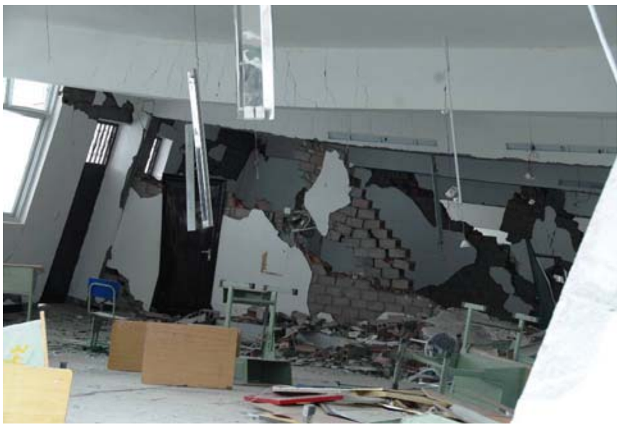

Fig. 8 The damaged classroom

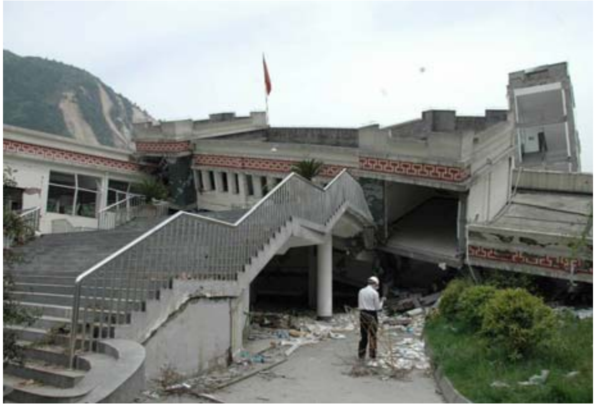

Fig. 9 The collapsed RC school building

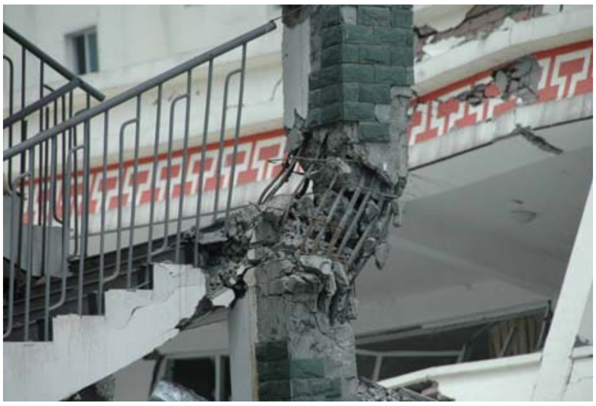

Fig. 10 The close-up of a damaged RC column

Fig. 11 The collapsed dormitory of a hospital

2.2 Hospitals

The hospitals suffered damages of different degrees from moderate to severe so they were not able to operate with normal function to rescue the injured and save lives right after this natural catastrophe. Figure 11 shows the collapsed buildings of a hospital at Hanwang. Figures 12-14 show hospitals with no service due to partial damages or lack of water and power.

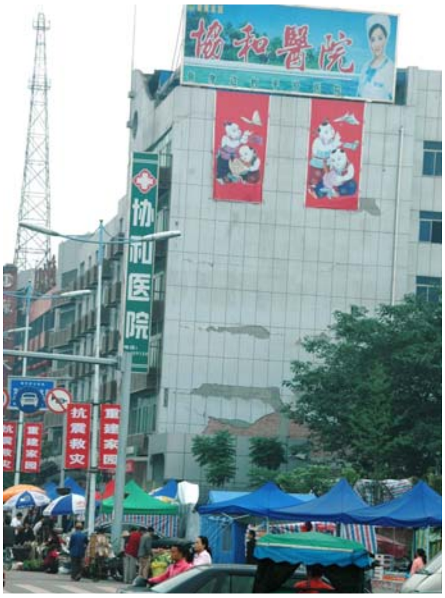

Fig. 12 The hospital suffered medium damages

Fig. 13 The structural damages of a hospital

Fig. 14 The hospital is out of service

2.3 Factory and Tower Structures

Most of the factories suffered structural or non-structural damages in this earthquake. The operations were almost shut down due to these damages as well as lack of electricity. Figures 15-17 show the damaged factories. However, there is a premix concrete factory in the affected area remains operation after the earthquake and provide enormous help to the community (figure 18).

Fig. 15 The damaged factory

Fig. 16 The collapsed factory

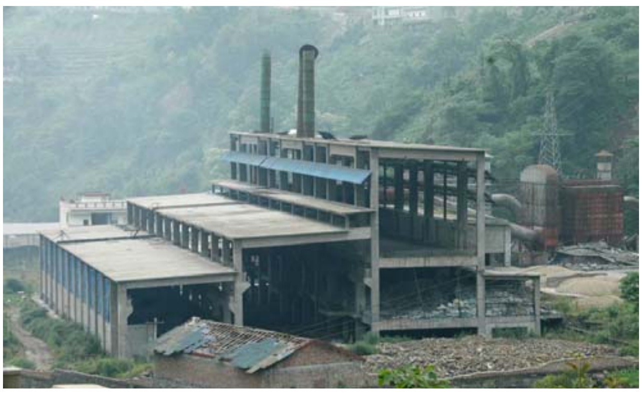

Fig. 17 The mess in the factory

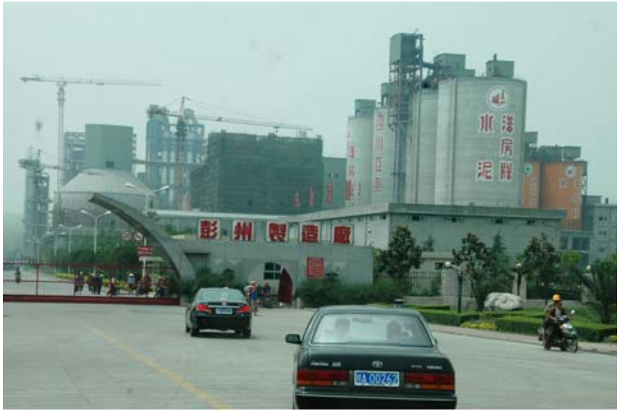

Fig. 18 The concrete premix factory was intact

More amazingly, there are a lot of undamaged high-rise structures found in the earthquake affected region. Figures 19-22 show such structures including towers, pagoda and chimneys. They may have a lower natural frequency than dominant frequency content of the seismic waveforms, which may have helped survive high accelerations.

Fig. 20 The high-rise pagoda

Fig. 19 The water tower is still standing

Fig. 21 Another undamaged water tower

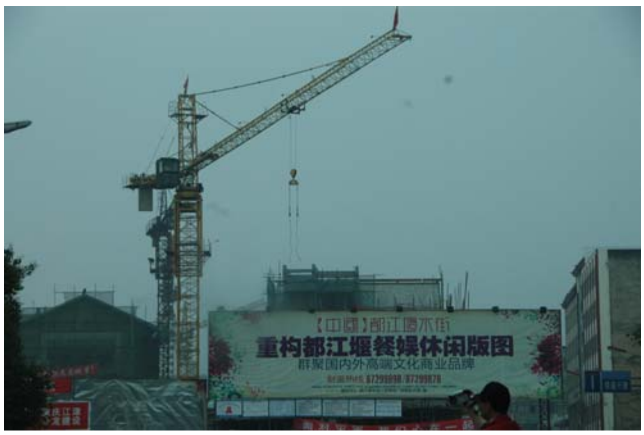

Fig. 22 The crane tower is still in operation

3. FIELD OBSERVATIONS ON BRIDGE DAMAGES

The damages of bridges are less serious as compared to those of the buildings. Among 33370 km of damaged roads, 4840 bridges and 98 tunnels were totally or partly destructed. There are several severe cases including Baihwa Bridge, Xiaoyudong Bridge, and Miaotzuping Bridge with some typical damages such as unseating spans, destructive shear keys, damaged expansion joints, fractured (buckling) piers and abutment, as well as loss of fence.

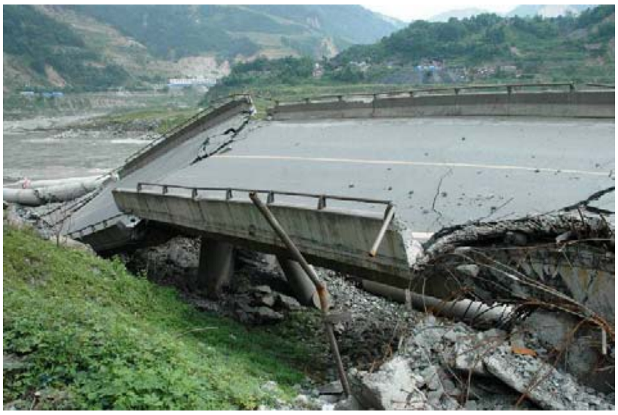

Fig. 23 The collapsed decks of Baihwa bridge

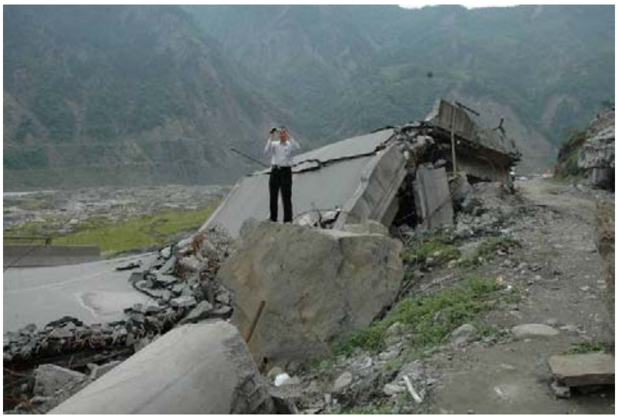

Fig. 24 The collapsed Baihwa bridge

3.1. Baihwa Bridge

Baihwa Bridge is a reinforced concrete (RC) slab beam continuous bridge supported by twin column pier with cap beam on expansion joint. It is a 500 m long, 30 m height viaduct and plays a critical role on the route from Dujiangyan to Wenchuan when opened to traffic since 2004. There are about 50 m long bridge slab collapsed on the location of the turning section after earthquake as shown in figures 23 and 24. Due to the safety reason, the un-collapsed part of Baihwa Bridge is demolished using explosives to reduce the threat to the emergency path underneath the bridge.

Fig. 25The collapsed spans of Xiaoyudong bridge

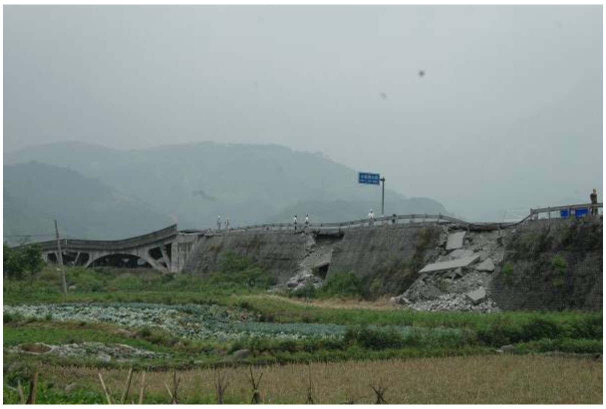

Fig. 26 Fault rupture went through the embankment of Xiaoyudong bridge

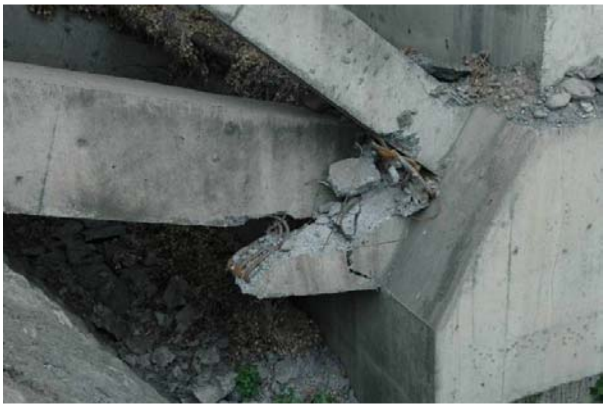

Fig. 27 The fractured element of Xiaoyudong bridge

3.2. Xiaoyudong Bridge

Xiaoyudong Bridge was a four-span RC arch bridge as shown in figures 25-27. The fault rupture and the strong motion of the earthquake caused the collapses of two spans and severely damaged the rest of the bridge. The destruction of the embankment, abutment and the barrier, the buckling of the arch, as well as the shifting of the road surface are all observed to witness the enormous pressure of the strong earthquake motion.

Fig. 28 The falling span of Miaotzuping bridge

3.3. Miaotzuping Bridge

As shown in figure 28, Miaotzuping Bridge is located at the Zipingpu dam water reservoir area near Dujiangyan. This beautiful bridge is 1436 m long with 108 m height composed of main bridge (long span continuous box girder type) and 19 approaches (T-girder simple supported with continuous deck). Though the main construction of the bridge is completed but it is not opened to traffic yet since the unfinished facilities. There are spans shifting on both longitudinal and horizontal directions causing the damages of shear keys on both sides. Furthermore, the earthquake caused one of the T-girder approaches collapsed due to possible insufficient support length of cap beam for falling prevention (narrow seat).

3.4. Other Bridges

Figure 29 shows a destroyed ancient masonry arch bridge at Bailu. In addition, the rest of the bridges on National Highway 213 were all suffered different degree of damage such as shifting, cracks on bridge support, and destructions of side stoppers (shear keys), as shown in figure 30. Since the bridges play very important roles on transportation and it is critical for emergency rescue and response tasks, the slightly damaged bridges were temporary retrofitted by Bailey bridge with speed and weight limit (figure 31).

Fig. 29 The destroyed arch bridge in Bailu

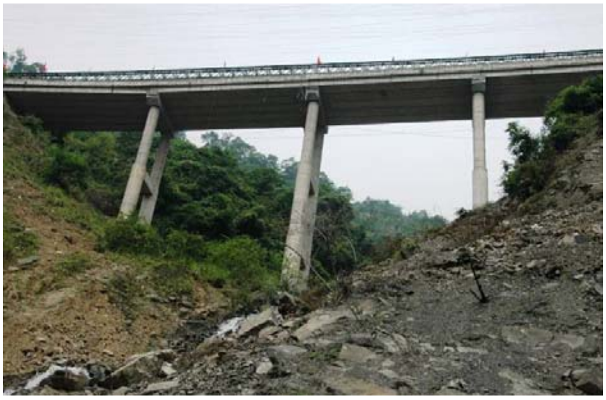

Fig. 30 The damaged bridge in Highway 213

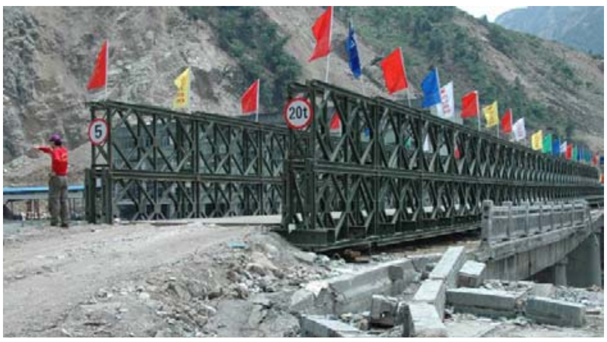

Fig. 31 The speed and weight limits on the Baileys

Also shown in figure 31, the bridges at Mianzhu city suffered slight damages on expansion joints although most of the bridges at metropolitan cities remain intact.

Fig. 32 The damaged expansion joint

4. OBSERVATIONS ON RESPONSE AND RECOVERY

Immediately after the earthquake, Chinese Prime Minister Wen Jiabao flied directly to the affected area near epicenter to command the whole emergency response and recovery activity. More than 100,000 China Army, police, fire fighters and civilian volunteers from other provinces came to Sichuan to join the rescue forces, as shown in figures 33-36. International rescue teams joined the missions three days later and saved thousands of lives together. Billions RMB budget were allocated for immediate relief and rescue efforts from the central Chinese government. Loads of water, foods, medical supplies, coals, diesels and construction materials were transported to quake-hit regions to help massive recovery task (figures 37-39). The destructed roads to the mountainous regions were immediately repaired, and made accessible for emergency transportation. The farmers began working on the rice field in affected zone two weeks after the earthquake.

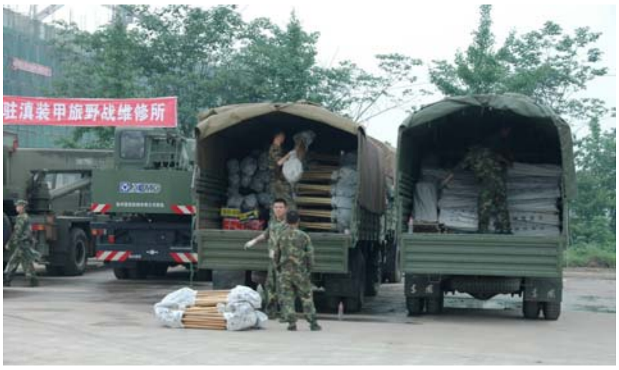

Fig. 33 The China army as rescue force

Fig. 34 The China army as rescue force

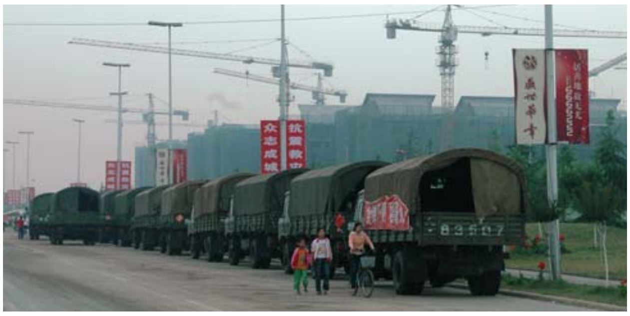

Fig. 35 The China army as rescue force

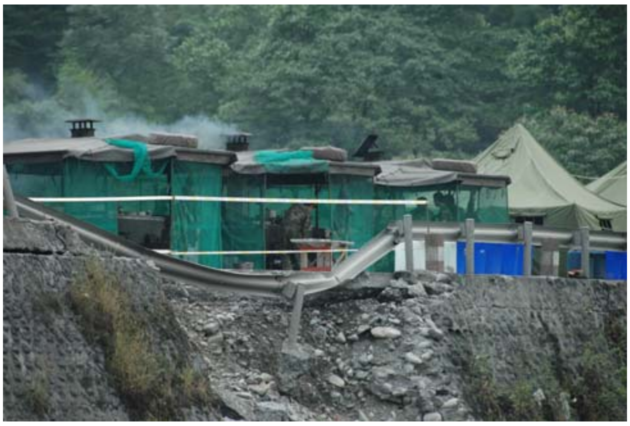

Fig. 36 The China army is guarding the damaged bridge

Fig. 37 The emergency tents at the refuge area

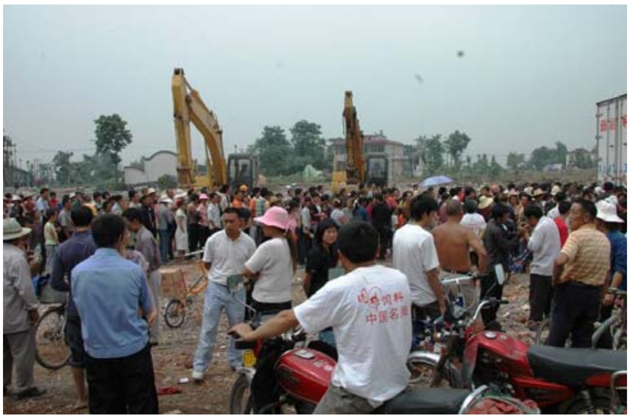

Fig. 38 The people lined up waiting for reliefs

Fig. 39 The farmers began to work 2 weeks after the earthquake

There are around 5 million people left homeless by the earthquake. Therefore, China's Ministry of Housing and Urban-Rural Development called on local authorities with help from other province to build 1.5 million temporary homes (shelters). Each unit can accommodate for 3 persons within 20 m^2 floor space. The quake refugees can live here for 3 years during the post-quake restoration of the city, as shown in figures 40-43.

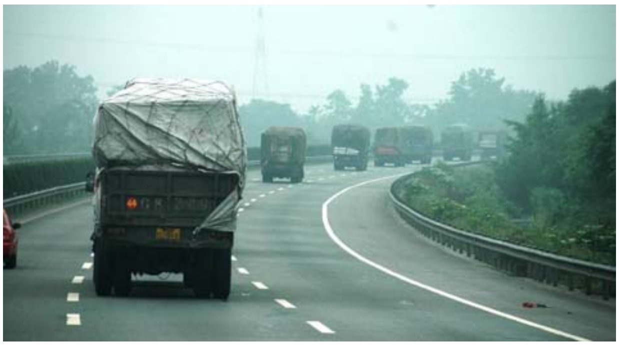

Fig. 40 The trucks delivering construction materials to Sichuan for temporary homes

Fig. 41 The material for temporary houses piles up next to the tents.

Fig. 42 The temporary houses under construction near Pongzhou.

Fig. 43 The community of finished temporary houses

5. CONCLUDING REMARKS

In earthquake prone regions, the earthquakes are part of human life and there is no way to get rid of them. However, we can learn how to survive earthquakes with better odds from past experience through updated science and engineering knowledge as well as state-of-the-art technologies. People have learned lessons from 1989 Loma Prieta (M7.0), 1994 Northridge (M6.7), 1995 Kobe (M7.2), and 1999 Chi-Chi (M7.6) earthquakes over the decades. To establish a better management system for hazard mitigation and to make a safer society in the future, here are some lessons the NCREE reconnaissance teams have learned from the Wenchuan earthquake:

(1) The existing requirements for seismic design forces in the code are lower than the demands observed from the Wenchuan earthquake. The new buildings will be able to perform better in severe earthquake events in the future through upgrading the code.

(2) The high seismic risk of building collapse for old or non-engineered structures can be considerably reduced through proper retrofitting schemes and past experience worldwide.

(3) Some common seen bridge failures such as insufficient length of seat width, cut-off lap-splice position, and lack of restrainer were still found in this China earthquake. Therefore, it is strongly recommended adopting the latest knowledge of disaster-prevention from other countries, so that the possible loss from earthquake can be minimized.

(4) Earthquake awareness and preparedness in the general public, especially schools, should be raised to a new level after the earthquake. Proper trainings and drills equipped with early warning system will reduce a large amount of the casualty.

(5) We should always expect the un-expected when facing the catastrophe and dealing with the risk management. Only the well preparation in every detail can reduce the damages made by natural hazard.

(6) Post-quake restoration is a long term multidisciplinary task, including rehabilitation and repair of a large number of existing buildings, recovery of heavily damaged or completely demolished communities, as well as timely comfort of severely suffered minds.

It is not only a tremendous amount of monetary budget but also efficient integrative administration from governmental sectors that the post-quake restoration requires in order to help refugees in the affected areas back to their normal life as early as possible. It is sincerely hoped that these reconnaissance information shared herein could help us to establish a better management system for hazard mitigation and to make a safer society in the future.

ACKNOWLEDGEMENTS

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