The 14th World Conference on Earthquake Engineering
October 12-17, 2008, Beijing, China

RECONNAISSANCE REPORT OF 0512 CHINA WENCHUAN EARTHQUAKE ON BRIDGES

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ABSTRACT :

On May 12, 2008 at 14:28 local time, an M_S8.0 earthquake struck the Sichuan Province, China. Millions of houses were destroyed and damaged, leaving approximately 4.5 million people homeless. The government reported around 69,200 dead (18,000 still missing) and 374,000 injured. Following the earthquake, the civil engineers of Taiwan immediately dispatched a team to the affected region on May 27th to collect information about structural and geotechnical damages as well as to provide helpful information for seismic assessment, retrofitting and rebuild planning. We may be the first reconnaissance team to reach the damaged area nearest to the epicenter to survey the schools, hospitals, residential buildings, landslides and bridges. From 27th May to 2nd June, we visited the area of Chengdu, Dujiangyan, Pongzhou, Shiaoyudong, Mianzhu, Zhiulong, Wudu, Hanwang, Hsuanko, Yingxiu (epicenter) and Highway 213. More than 5000 photos were taken to document the damages this catastrophic earthquake had made. This information should help us in preparation of disaster mitigation plan. This paper will focus on the damages on different types of bridges including simple support, arch and continuous elements. We would also like to take this opportunity to express our condolence for those who suffered from this earthquake. It is hoped that the information shared herein could help the community in making a safer society in the future.

KEYWORDS: Wenchuan earthquake, reconnaissance, bridges damages, simple support

1. INTRODUCTION

On May 12, 2008 at 14:28 local time, an M_S8.0 earthquake struck the Sichuan Province, China. Millions of houses were destroyed and damaged, leaving approximately 4.5 million people homeless. The government reported around 69,200 dead (18,000 still missing) and 374,000 injured. Following the earthquake, the civil engineers of Taiwan immediately dispatched a team to the affected region on May 27th to collect information about structural and geotechnical damages as well as to provide helpful information for seismic assessment, retrofitting and rebuild planning. We may be the first reconnaissance team to reach the damaged area nearest to the epicenter to survey the schools, hospitals, residential buildings, landslides and bridges. Since then, several reconnaissance teams from Taiwan visited the area of Chengdu, Dujiangyan, Pongzhou, Xiaoyudong, Mianzhu, Zhiulong, Wudu, Hanwang, Bailu, Hsuanko, Xanzhao, Yingxiu (epicenter) and Highway 213. More than 5000 photos were taken to document the damages this catastrophic earthquake had made. This information should help us in preparation of disaster mitigation plan. This paper will focus on the damages on different types of bridges including simple support bridges, arch bridges and continuous girder bridges.

2. BRIDGE DAMAGES

The damages of bridges are lesser as compared to the damages of the structures. Totally 33370 km of road was reported damaged by officials. Among these, 4840 bridges and 98 tunnels were totally or partly damaged. There are several severe cases, which are Baihwa Bridge, Xiaoyudong Bridge, Bailu Bridge, and Miaotzuping Bridge, from our observation. The damage conditions as well as the photos were described in the following sections.

2.1. Baihwa Bridge

Baihwa Bridge is a 500 m long viaduct with 30 m height, and plays a critical role on the route from Dujiangyan to Wenchuan. Construction finished in 2004, it is a reinforced concrete (RC) slab beam continuous bridge supported by twin column pier with cap beam on expansion joint and twin column without cap beam at other places. As shown in figures 1-6, there are about 50 m long bridge slab collapsed on the location of the turning section after earthquake. Due to the safety reason, the un-collapsed part of Baihwa Bridge is exploded to reduce the threat to the emergency path underneath the bridge.

Fig.1 The falling slab of Baihwa Bridge

Fig.2 The broken slab and pier of Baihwa Bridge

Fig.3 The falling slab of Baihwa Bridge

Fig.4 The falling slab of Baihwa Bridge

Fig. 5 The exploded pier of Baihwa Bridge

Fig.6 The abutment of Baihwa Bridge

2.2. Xiaoyudong Bridge

As shown in figures 7-14, Xiaoyudong Bridge was a four-span RC arch bridge. The strong motion of the earthquake and the fault rupture caused the collapses of two spans and severely damaged the rest of the bridge spans. The destruction of the embankment, abutment and the barrier, the buckling of the arch, as well as the shifting of the road surface are also observed to witness the enormous pressure of the strong earthquake motion.

Fig.7 Damage of the Xiaoyudong bridge

Fig.8 Fault rupture was observed


Fig. 9 Deck damage at approach


Fig.10 Damage of the embankment


Fig.11 Spandrel element fracture


Fig.12 Fracture at connection between arch and abutment


Fig.13 The fallen spans of the Xiaoyudong Bridge


Fig.14 Horizontal displacement of the spans

2.3. Miaotzuping Bridge

Miaotzuping Bridge is located at the water reservoir area (Zipingpu dam) near Dujiangyan. As shown in figures 15-18. This beautiful bridge is 1436 m long with 100 m height composed of main bridge (long span box girder bridge) and 19 approaches (T-girder bridge). The construction of the bridge is completed but not opened to traffic yet. There are spans shifting on both longitudinal and horizontal directions causing the damages of side stoppers. Besides, the earthquake caused one of the T-girder approaches collapsed due to possible insufficient support length of cap beam for falling prevention (narrow seat).

Fig.15 The approached of Miaotzuping Bridge

Fig.16 On top of Miaotzuping Bridge

Fig.17 Horizontal shift of spans

Fig.18 Damage of the side stopper

2.4. Bridges on Highway 213

The rest of the bridges on Highway 213, all suffered different degree of damage such as shifting, cracks on bridge support, and destructions of side stoppers (as shown in figures 19-24). However, there is less damage on pier such as crack or buckling found from our observation. 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 25) or detoured using tubes and grading (figure 26) to make an emergency detour.

Fig.19 Horizontal shifts of the decks

Fig.20 No damages observed on piers

Fig.21 Damages on side stoppers

Fig.22 Damage on abutment

Fig.23 Damage on expansion joint

Fig.24 Damages on barrier and expansion joint

Fig.25 Bailey bridge with speed and weight limits

Fig.26 Emergency detour of Xiaoyudong bridge

2.5. Arch Bridge at Bailu

As shown in figures 27-28, the Bailu arch bridge was collapsed due to the strong earthquake motion. The emergency detour was constructed by military using the precast concrete planks immediately since the bridge is the only path to reach out side world for the community.

Fig.27 Collapsed arch of Bailu bridge

Fig.28 Damaged Bailu bridge and the emergency detour

2.6. Other Bridges at Cities

Most of the bridges at metropolitan cities remain intact, as shown in figures 29-30. However, the bridges at Mianzhu city suffered slight damages on expansion joints and remain in service with warning sign, as shown in figures 31-32.

Fig.29 Viaduct at Chengdu

Fig.30 Bridge at Dujiangyan

Fig.31 Expansion joint damage at Mianzhu

Fig.32 Warning Sign for bridge at Mianzhu

3. DAMAGES CAUSES

The following observations can be obtained from these damaged bridges:

(1) The support length of the pier to prevent the bridge slab from falling is not long enough (narrow seat).

(2) There is no shear key but only side stopper, and most of the stopper is not strong enough to remain intact but they did stop the bridge from falling laterally.

(3) There is barely bearing system, especially no isolator or rubber bearing, on top of the pier to

support the bridge as well as to dissipate the earthquake energy.
(4) There is no restrainer found on bridges to prevent the spans from falling.
(5) Insufficient flexural strength and displacement ductility are leading to the brittle failure.
(6) Joint failure comes from the poor detailing of the lateral reinforcements and ties.
(7) Weak surface in the column are often found because of inadequate cut-off and lap-splice of the longitudinal reinforcements.
(8) Torsion failure, induced by moment coupling effect and pull-off failure of the bearings in the curved bridge, will increase the opportunity of fallen spans.

Besides, with the magnitude of 8, this earthquake may require higher seismic force than the one determined by the current design specification. Recently, countries suffered damages from earthquakes are updating their design code to accommodate the latest modifications. However, issued in 1989, the current seismic design specifications of bridges（JTJ004－89）has been using for more than 20 years without any further new modifications on the topics such as the detail of lap splices, arrangement of lateral reinforcements, and falling-prevention system. Meanwhile, none of the experiences learned from the recent earthquakes was referenced in the current code. Therefore, an out-of-date design code might be one of the reasons to explain why the damages of the bridges could be found in this earthquake event.

4. SUMMARY

To repair the damage of the bridges and to retrofit the bridges after the earthquake are very important to prevent the further disaster. Besides, the investigation on the causes of the bridge damages can help us to improve the seismic code for bridges. Learning from the past earthquakes and prevent similar damages is as important as the retrofitting task after the earthquake disasters. Over the decades, people have learned lessons from Loma Prieta earthquake (M7.0) in 1989, Northridge earthquake (M6.7) in 1994, Kobe earthquake (M7.2) in 1995, and Chi-Chi earthquake (M7.6) in 1999. The concept of ductile pier or innovative device such as lead rubber bearing, pendulum friction bearing, shear key and restrainer are proposed by researcher and implemented in practical use after several moderate earthquakes in the world. However, some common seen failures such as insufficient length of seat width, cut-off lap-splice position were still found in Wenchuan 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. Take Taiwan experience for example, though the ductile design concept and unseat prevention devices for new bridges have been developed since Northridge and Kobe earthquakes, it was until the 1999 Chi-Chi earthquake with immense damages of the bridges that people realized the importance of retrofitting task of existing bridges. Earthquake is part of the life and there is no way to avoid but to learn from the past and share knowledge of anti-seismic with other countries to pursuit better seismic design methods.

ACKNOWLEDGEMENTS

We gratefully acknowledge Sichuan Association for Science and Technology (SCAST), and Sichuan branch of the Taiwan Affairs Office of the State Council for their kindness, enormous help and friendships when the team conducting earthquake reconnaissance investigation.

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