Performance of Transportation Infrastructure During the Wunchuan Earthquake, China on May 12, 2008

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SDR Monthly Meeting
October 9, 2008

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Sichuan Earthquake Parameters

Ms 8.0

- Date/Time: 2008-05-12 14:28:04.0
- Latitude: 31.0
- Longitude: 103.4
- Epicenter Depth: 33Km
- Magnitude: Ms8.0
- Epicenter: Sichuan Province Wunchuan County
- Damaged Area: 200Km radius

- Dujianyan 21km(267°) Chongqing 48km(327°)
- Dayiling 48km(346°) Chengdu75km(302°)

The Sichuan earthquake of May 12, 2008, occurred as the result of movement on a north-south striking reverse fault or thrust fault in the southwestern margin of the Sichuan Basin. The earthquake resulted in a devastating event that resulted in the death of millions of people and massive destruction of property. The earthquake also caused a large number of aftershocks, with some aftershocks reaching magnitude 7.0. The epicenter of the earthquake was located in the Wunchuan County of Sichuan Province, China. The earthquake caused significant damage to the surrounding areas, with a damaged area of approximately 200Km radius.

One contributing factor to the magnitude of the earthquake was the stress accumulation on the fault due to the tectonic movement of the Tibetan Plateau. The movement of the Tibetan Plateau has caused significant stress accumulation on the surrounding areas, leading to the occurrence of earthquakes. The Sichuan earthquake was one of the most severe earthquakes in recent history, causing significant damage and loss of life.

The effects of the earthquake were felt across a wide area, with aftershocks recorded in the surrounding regions. The earthquake also caused significant damage to infrastructure, with many buildings and bridges collapsing.

The immediate response to the earthquake was a massive rescue effort, involving a large number of rescue workers and volunteers. The government also launched an emergency response plan to provide assistance to the affected areas.

The Sichuan earthquake was a tragic event that highlighted the need for better earthquake preparedness and response strategies. The government and international organizations worked together to provide assistance to the affected areas and to prevent future disasters.

The Sichuan earthquake also raised awareness about the importance of tectonic activity and the need for better understanding of the underlying geological processes. The earthquake was a reminder of the importance of scientific research and the need for continued monitoring of tectonic activity.

The Sichuan earthquake had a significant impact on the global community, with numerous countries and organizations offering aid and support to the affected areas. The Sichuan earthquake was a tragic event that highlighted the need for continued scientific research and the importance of disaster preparedness.
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Seismic Hazard

Estimated Population Exposed to Earthquake Shaking

Population Exposure

Selected City Exposure

Overall, structures in the region are vulnerable to earthquake shaking, though some isolated structures exist. A magnitude 6.4 earthquake shook the Sichuan, China region on August 15, 2008 UTC, with estimated population exposures of 1.75 million at intensities VI and VII, and 5.75 million at intensities VII and VIII resulting in 41 deaths. Additionally, a magnitude 7.0 struck this region in 1930 killing 60,000 people. Recent earthquakes in this area have also triggered landslide hazards that have contributed to losses. Users should consider the preliminary nature of this consultation and check for updates as additional data becomes available.

http://earthquake.usgs.gov/pager
Observed ground motion

- Observation at Bajiao Seismological Station, Shifang City (see Zifa Wang, J. EEEV., June '08)
- High vertical component of acceleration
19,412 total aftershocks
the strongest aftershock 6.4 Magnitude
5 times 6.0 to 6.9 Magnitude;
29 times from 5.0 to 5.9 Magnitude
203 times ranged from 4.0 to 4.9 Magnitude

Official data (as of July 13, 2008 12:00 CST)

- 69,197 are confirmed dead, including 68,636 in Sichuan province,
- 374,176 injured,
- 18,379 listed as missing.
- about 4.6 million homeless.
Team members:
1. W. Phillip Yen (FHWA, Team Leader)
2. Mark Yashinsky (Caltrans)
3. Youssef Hashash (GEER/ UIUC)
4. Genda Chen (Missouri S&T)
5. Curtis Joseph Holub (UIUC)
6. Kehai Wang (RIOH, China)
7. Xiaodong Guo (Sichuan DOT, China)

Earthquake affected highway area:
- Roadway: 53,295 km
- Bridges: 5,560
- Tunnels: 110

RMB 58 billion loss.
Three national and provincial highways still closed.
Surface Rupture of the Earthquake Fault
Surface Rupture along the Old Highway near the Collapsed Building

Surface Feature of Fault Rupture near the Xiaoyudong Bridge

Xiaoyudong Bridge (31.1859N, 103.7677E)  Near by the Bridge
Xiaoyudong Bridge (31.1859N, 103.7677E)

Xiaoyudong bridge (4 spans continuous arch frame)
Tension cracks on deck area
Shunhe bridge totally collapsed in Yingxiu (bridge longitudinal direction was parallel to the fault line)

Landslide buried the bridge on Ying-Ri Road

Landslide crushed the bridge on Du-Wen Road
Nanba Bridge

- Fault rupture caused the bridge span to collapse.
- Decks were pushed to abutment area.
- 10 spans with 25m/span
- Bridge was under construction
- Simply supported girders

Side view

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Pull-off-and-drop collapse of bridge deck

- Miaoziping bridge
  - One span of was unseated during the earthquake.
  - Bridge was under construction
Miaoziping bridge:

• Simply supported spans, one span collapsed
• Rigid frame spans, little damage

Temporarily Connecting Walkway
1. Constructed in 2004
2. 18 spans and 450m long
3. Piers, bearings and tie beams failures
4. 5 curved spans totally collapsed
5. Demolished after the earthquake
Baihua bridge (after demolished)

2008/07/23

Baihua bridge (after demolition)

2008/07/23
7. Baihua bridge

9. Straight bridges has better performance than the curve bridges
Gaodian bridge in Wenchuan
Offset in transverse direction

Mianchi bridge
Offset in transverse direction
Shear key failure

Damages of roadway

Rupture

Upheaval
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Damages of roadway

Settlement  Crushing
cave-in collapse caused by the failure of the retaining wall
Damages of roadway

Landslide up to 200 meter
1. landslide, mudslide

Typical damages of side slope

2008/05/24

Typical damages of Retaining Walls
Falling Rocks

Tunnel Damages
Tunnel & side slope damages

tunnel-liner cracks
Tunnel Damages

Construction joint offset

inverted upheaval

Collapsed buildings
Slightly damaged building

Temporary Quarters
Lessons Learned

- Transportation structures are very vulnerable
  - Emergency response is very critical to response and recovery
- Bridge design affects performance
  - Highly skewed & curved bridges should be avoided in high intensity earthquake zones
  - Shear failures must be avoided in piers
  - Shear keys are required to prevent spans from falling transversely
  - Bridge stiffness distribution needs to be balanced
- Earthquake response
  - Near-field ground motions need to be considered
  - Ground motion with longer duration needs to be studied

Concerned Issues

- Loading Path of Seismic Design
- Shear Key Design
- High Piers Design
- Near Fault Effects
- Bearing Design
- Restoration
- Retrofitting

- How to reconstruct a bridge crossing a known & active fault?
Thank you!

For further information, please contact Dr. W. Phillip Yen at Wen-huei.Yen@fhwa.dot.gov