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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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Outline

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- Other Facilities
- Lessons Learned
- Issues of Concern

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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°)

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TECTONIC SUMMARY

0 100 200 400

The Sichuan earthquake of May 12, 2008, occurred as the result of motion on a northeast striking reverse fault or thrust fault on the northwestern margin of the Sichuan Basin. The earthquake's epicenter and focal-mechanism are consistent with it having occurred as the result of movement on the Longmenshan fault or a tectonically related fault. The earthquake reflects tectonic stresses resulting from the convergence of crustal material slowly moving from the high Tibetan Plateau, to the west, against strong crust underlying the Sichuan Basin and southeastern China.

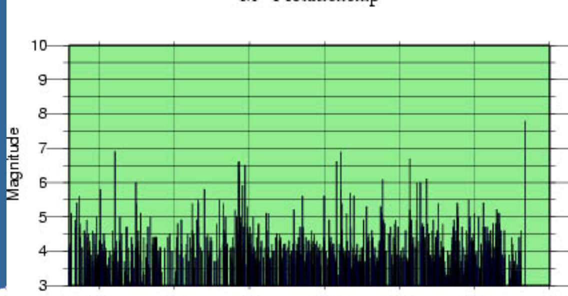
On a continental scale, the seismicity of central and eastern Asia is a result of northward convergence of the India plate against the Eurasia plate with a velocity of about 50 mm/y. The convergence of the two plates is broadly accommodated by the uplift of the Asian highlands and by the motion of crustal material to the east away from the uplifted Tibetan Plateau.

The northwestern margin of the Sichuan Basin has previously experienced destructive earthquakes. The magnitude 7.3 earthquake of

Significant Earthquakes Mag >= 7.0

Year	Mon	Day	Time	Lat	Long	Dep	Mag
1917	07	30	2354	29.000	104.000	0	7.3
1923	03	24	1240	30.553	101.258	25	7.2
1933	08	25	0750	31.810	103.541	25	7.3
1947	03	17	0819	33.000	99.500	0	7.5
1948	05	25	0711	29.500	100.500	0	7.2
1950	08	15	1409	28.500	96.500	0	8.6
1955	04	14	0129	29.981	101.613	10	7.5
1967	08	30	0422	31.631	100.232	8.1	7.0
1973	02	06	1037	31.361	100.504	6.6	7.4
2008	05	12	0628	31.099	103.279	10	7.9

M–T relationship



ERENCES

l, P., 2003, An updated digital model of plate boundaries: ochem. Geophys. Geosyst., v. 4, no. 3, pp. 1027- 80.

dahl, E.R. and Villaseñor, A., 2002, Global Seismicity: 00 - 1999, chap. 41 of Lee, W.H.K., and others,eds., ernational Earthquake and Engineering Seismology, rt A: New York, N.Y., Elsevier Academic Press, 932 p.

dahl, E.R., Van der Hilst, R.D., and Buland, R.P., 1998, obal teleseismic earthquake relocation with improved trav- times and procedures for depth determination: Bull. Seism. c. Amer., v. 88, p. 722-743.

Distance do
Dip 33° North

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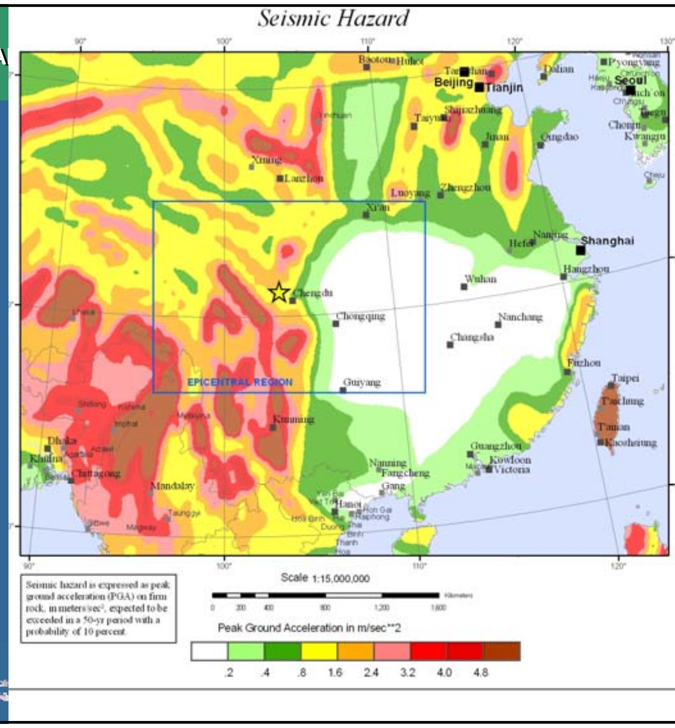

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USAID
FROM THE AMERICAN PEOPLE

M 7.9, EASTERN SICHUAN, CHINA

Origin Time: Mon 2008-05-12 06:28:01 UTC
Location: 31.02°N 103.37°E Depth: 19 km

PAGER
Version 8
Created: 1 days, 8 hrs after earthquake

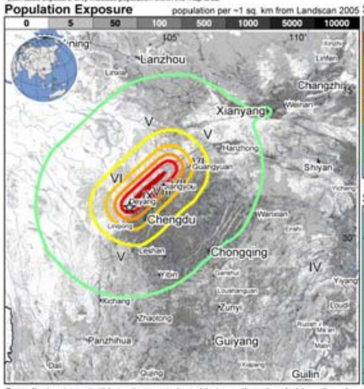
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		--*	--*	188,523k*	89,143k	15,400k	12,673k	3,897k	707k	610k
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan 2005

0	5	50	100	500	1000	5000	10000

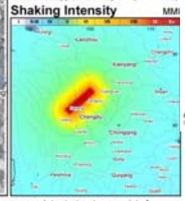


Selected City Exposure

MMI	City	Population
VIII	Jiangyou	127k
VIII	Tianpeng	60k
VII	Deyang	152k
VII	Linqiong	55k
VII	Chengdu	3,950k
VII	Mianyang	264k
VII	Guangyuan	213k
V	Nanchong	7,150k
V	Chongqing	3,967k
V	Lanzhou	3,200k
IV	Shiyan	3,460k

bold cities appear on map (k = x1000)

Shaking Intensity MMI



Overall, structures in this region are vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 6.4 earthquake struck the Sichuan, China region on August 23, 1976 (UTC), with estimated population exposures of 1,500 at intensity IX or greater and 5,700 at intensity VIII, resulting in 41 deaths. Additionally, a magnitude 7.3 struck this region in 1933 killing 6,800 people. Recent earthquakes in this area have also triggered landslide hazards that have contributed to losses. Users should consider the preliminary nature of this information and check for updates as additional data becomes available.

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager Event ID: us2008ryan

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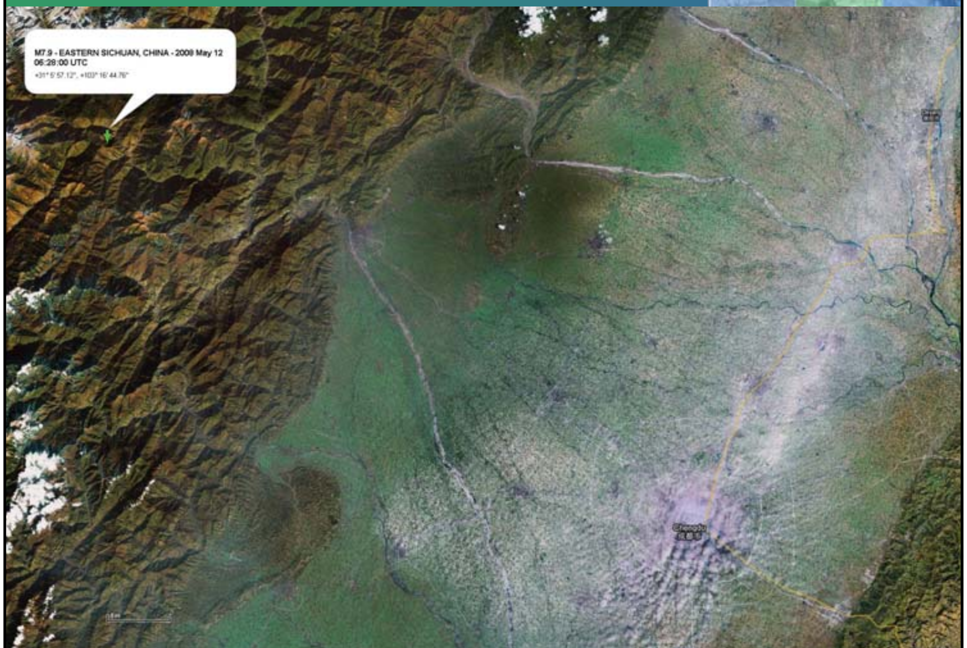
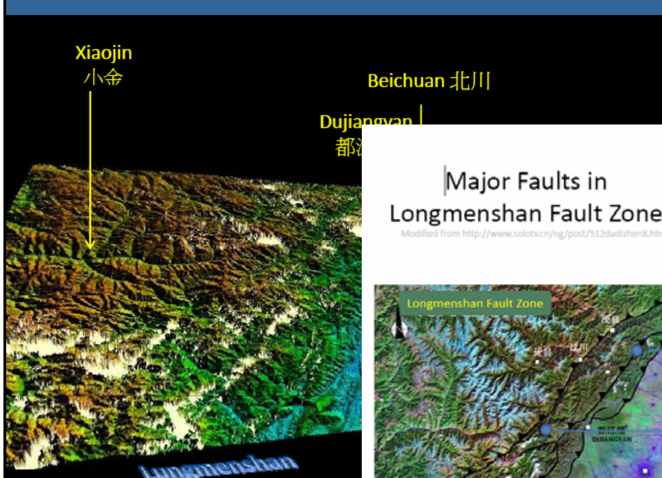
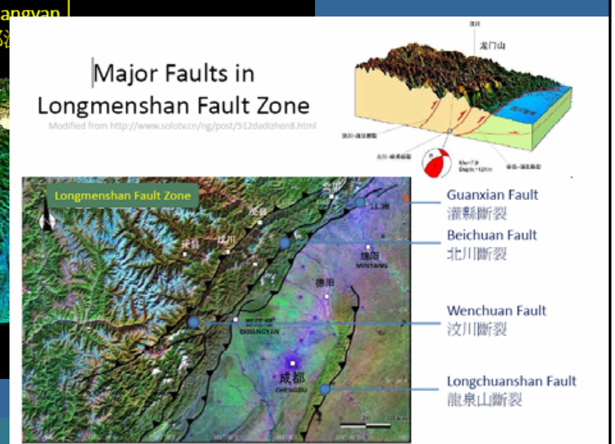


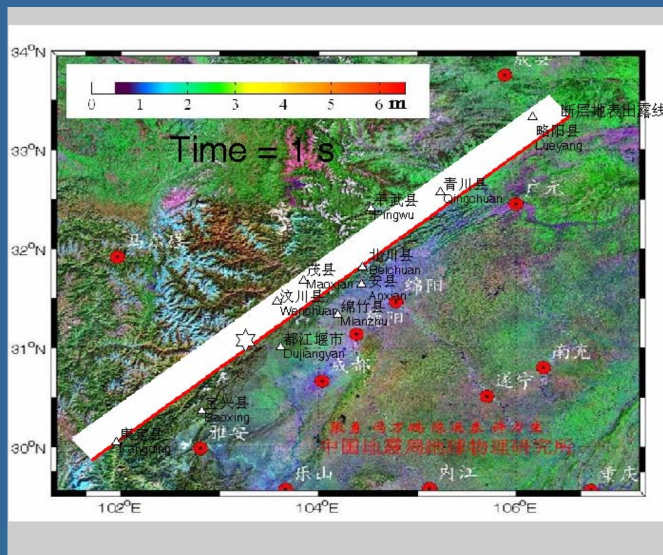
M7.9 - EASTERN SICHUAN, CHINA - 2008 May 12
06:28:00 UTC



Xiaojin
小金
Beichuan 北川
Dujiangyan
Lungmenshan



Major Faults in
Longmenshan Fault Zone
Longmenshan Fault Zone
Guanxian Fault
灌縣斷裂
Beichuan Fault
北川斷裂
Wenchuan Fault
汶川斷裂
Longchuanshan Fault
龍泉山斷裂



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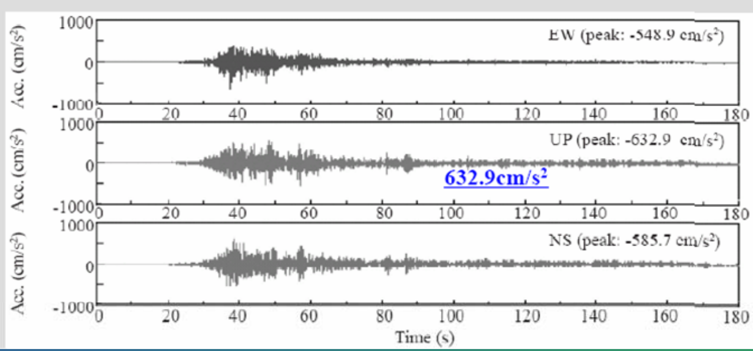
Observed ground motion

- Observation at Bajiao Seismological Station, Shifang City (see Zifa Wang, *J. EEEV*., June '08)
- High vertical component of acceleration



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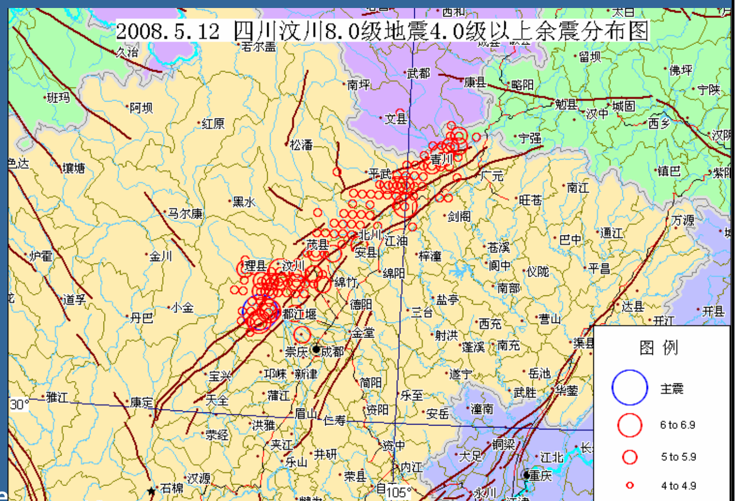
- 19,412 total aftershocks
- the strongest aftershock 6.4 Magnitude
- 5 times 6.0 to 6.9 Magnitude;
- 29 times from 5.0 to 5.9 Magnitude
- 203 times ranged from 4.0 to 4.9 Magnitude



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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/ UI
4. Genda Chen (Missouri S&T)
5. Curtis JosephHolub (UIUC)
6. Kehai Wang (RIOH, China)
7. Xiaodong Guo (Sichuan DOT, China)

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

RMB 58 billion loss .
Three national and provincial highways still closed.

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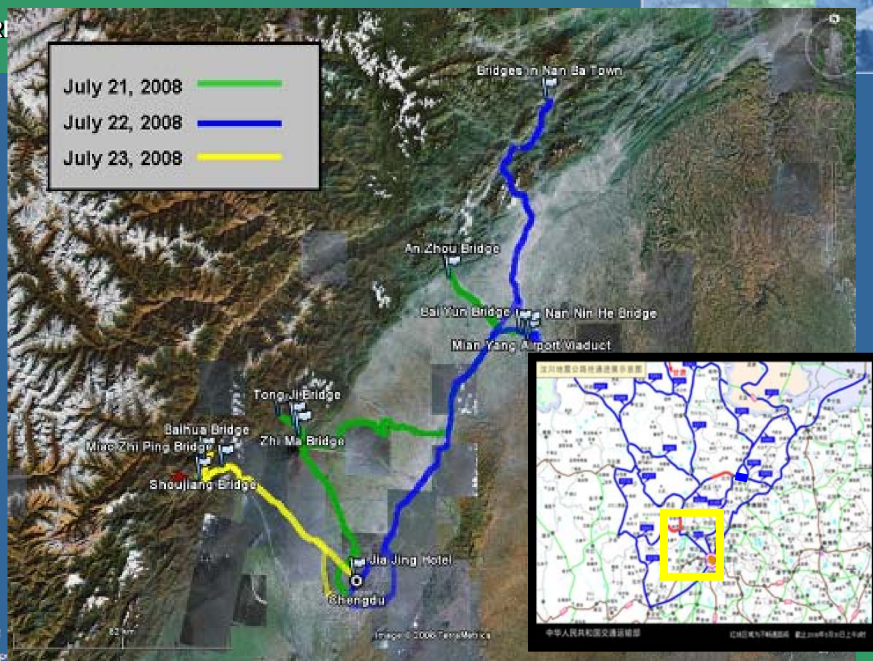

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Surface Rupture of the Earthquake Fault

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Surface Rupture along the Old Highway near the Collapsed Building

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Surface Feature of Fault Rupture near the Xiaoyudong Bridge

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

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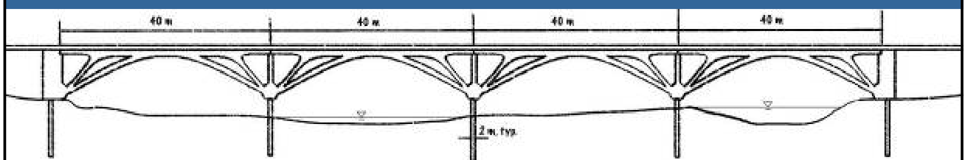
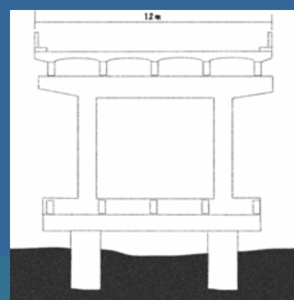
Xiaoyudong Bridge (31.1859N, 103.7677E)





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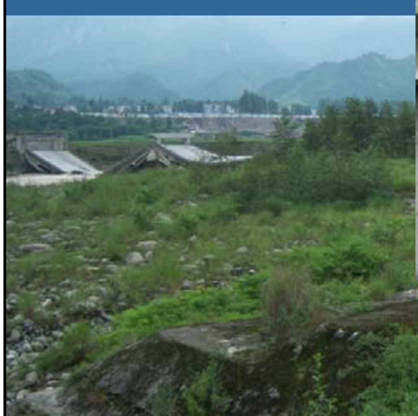

Xiaoyudong bridge (4 spans continuous arch frame)

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Tension cracks on deck area


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Shunhe bridge totally collapsed in Yingxiu (bridge longitudinal direction was parallel to the fault line)

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Landslide buried the bridge on Ying-Ri Road

Landslide crushed the bridge on Du-Wen Road

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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

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Side view

Pull-off-and-drop collapse of bridge deck

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- 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

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Temporarily Connecting Walkway

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Baihua bridge

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

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Baihua bridge (after demolition)

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Baihua bridge(after demolished)

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Baihua bridge (after demolition)

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7、Baihua bridge

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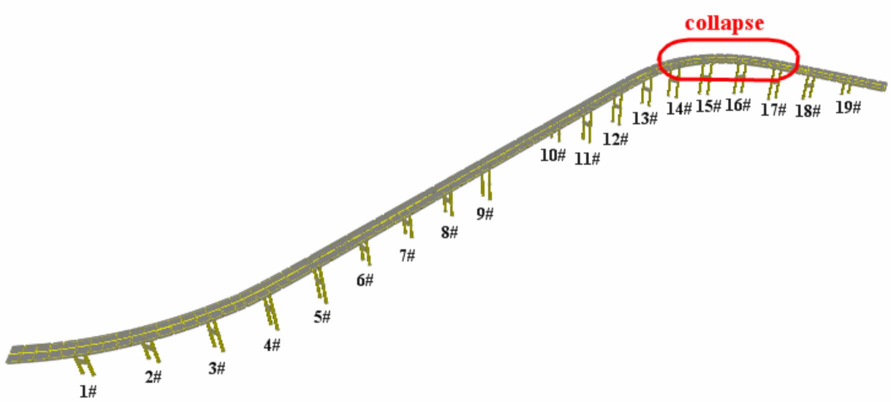
9. Straight bridges has better performance than the curve bridges



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Gaodian bridge in Wenchuan

Offset in transverse direction

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Offset in transverse direction

Mianchi bridge

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Shear key failure

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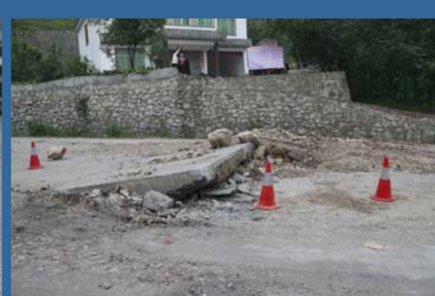
Damages of roadway

Rupture



Upheaval

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Rupture

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Damages of roadway

Settlement

Crushing

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Damages of roadway

cave-in collapse caused by the failure of the retaining wall

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Damages of roadway

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Damages of roadway

Landslide up to 200 meter

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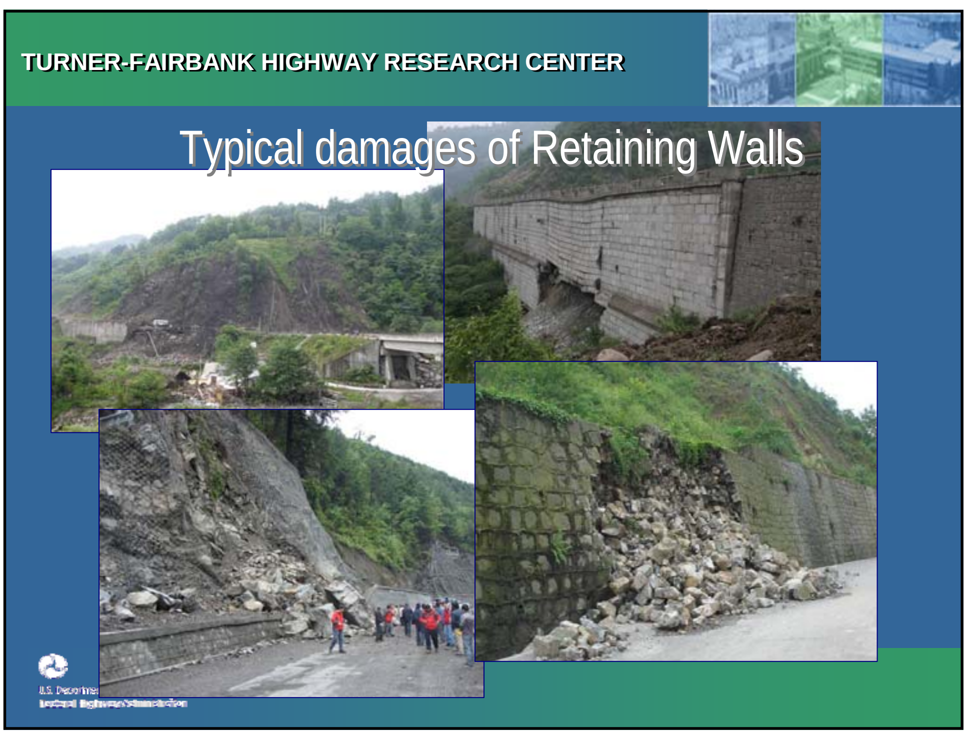
2008/05/24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Typical damages of Retaining Walls

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Tunnel Damages

Tunnel & side slope damages

tunnel-liner cracks

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Tunnel Damages

Construction joint offset

inverted upheaval

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Collapsed buildings

Slightly damaged building

Temporary Quarters

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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

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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?

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Thank you!

For further information, please contact Dr. W. Phillip Yen at
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