Investigation of the Effect of the May 2008 Earthquake on Bridges in China

Original presentation in China by Dr. Banfu Yan of
Hunan University, Changsha, China

Presentation modified in Canada by
Dr. Atab Mufti, Dr. Baidar Bakht & Mr. Walter Saltzberg

Translation of Dr. Yan's presentation done by Mr. Cheng Zhang, M.Sc. Candidate
and Mr. Walter Saltzberg ISIS Consultant
University of Manitoba

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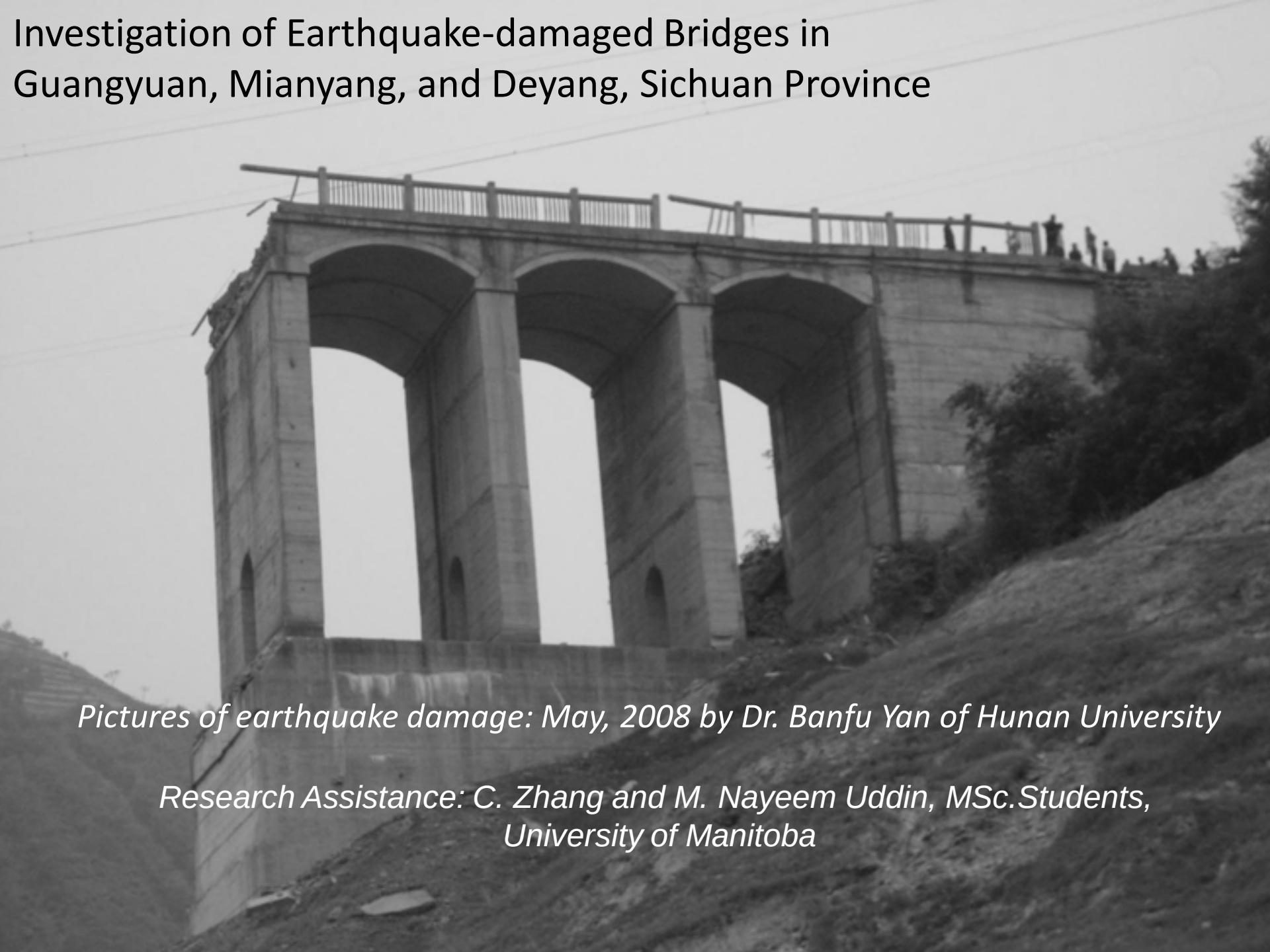
Investigation of Earthquake-damaged Bridges in Guangyuan, Mianyang, and Deyang, Sichuan Province

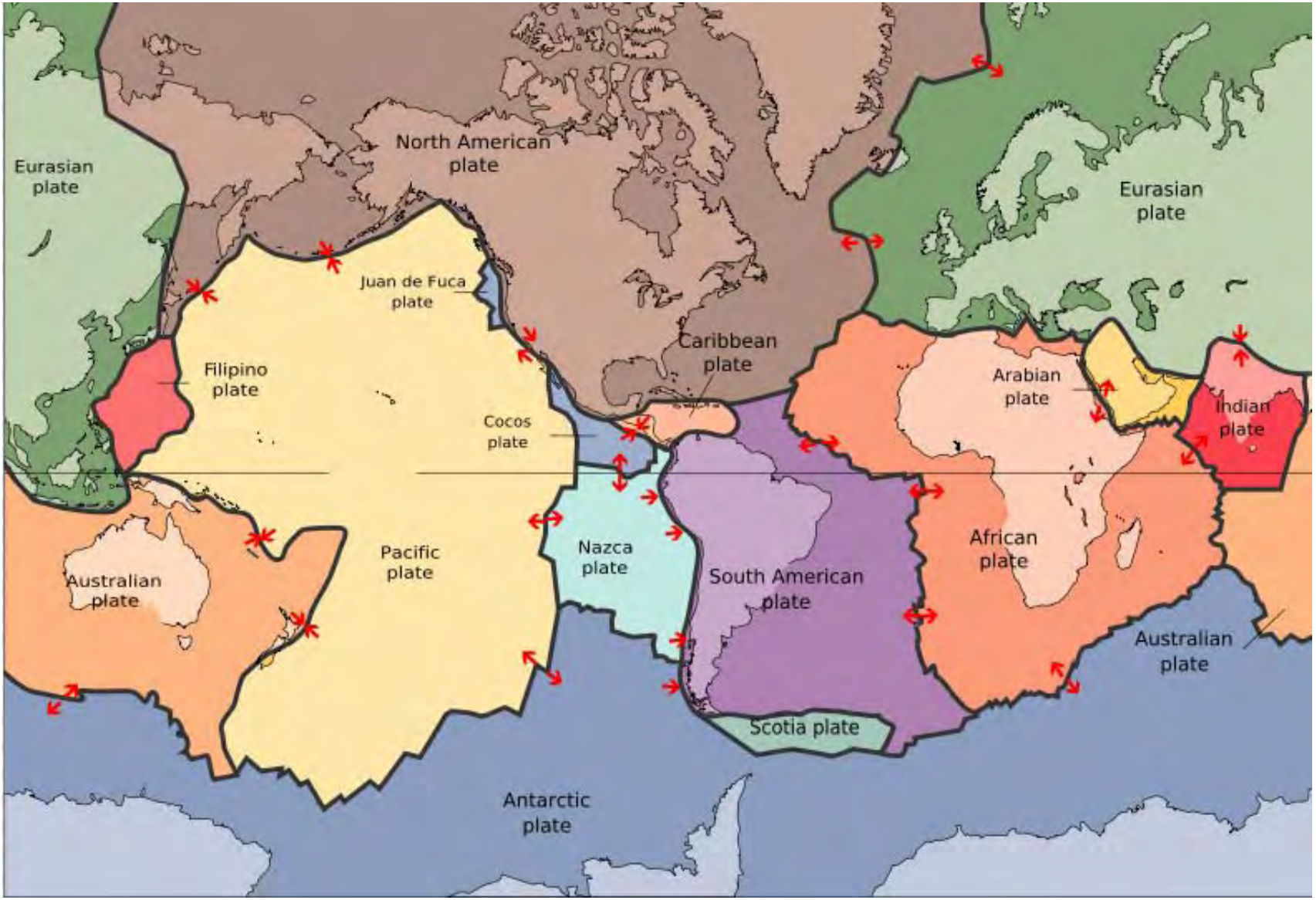


Pictures of earthquake damage: May, 2008 by Dr. Banfu Yan of Hunan University

Research Assistance: C. Zhang and M. Nayeem Uddin, MSc.Students, University of Manitoba

Information About Sichuan Province

Administration type:	Province
Capital: (and largest city)	Chengdu
Area:	485,000 km^2 (187,000 sq mi) (5^{th})
Population (2004) -Density	87,250,000 (3^{rd}) 180 /km^2 (470 /sq mi) (22^{nd})
GDP (2006) - Per capita	CNY 863.8 billion (9^{th}) CNY 10,574 (25^{th})
Industrial Base	Agriculture / Auto - Aerospace Manufacture

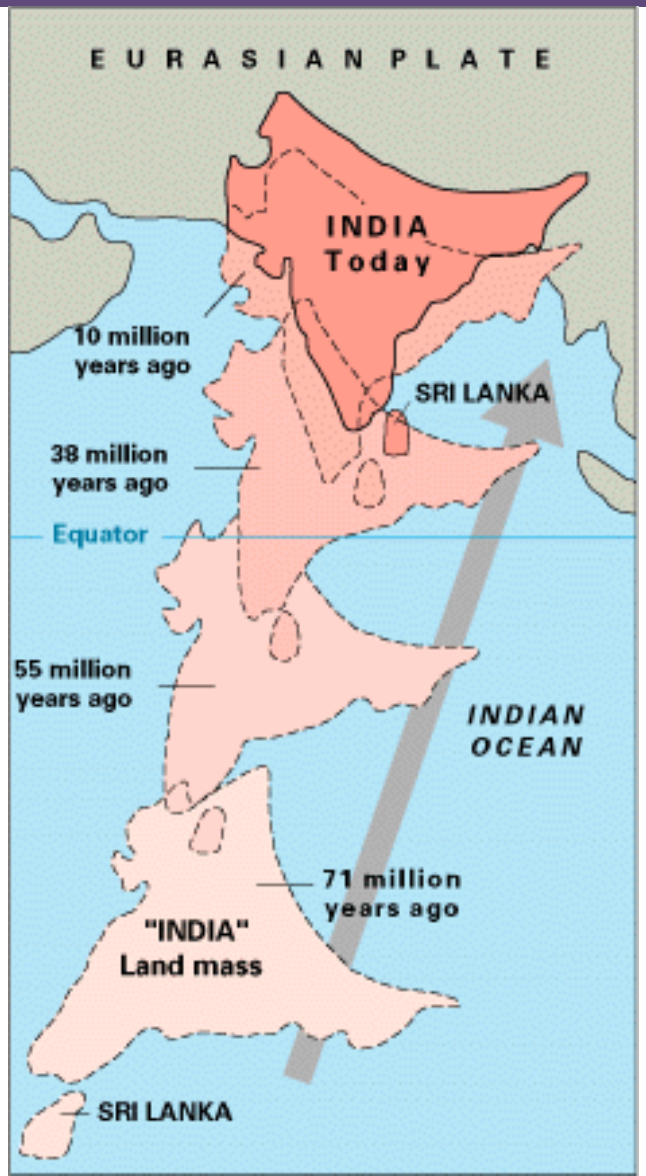


Picture from Wikipedia - Tectonic plates dividing the surface of the earth.

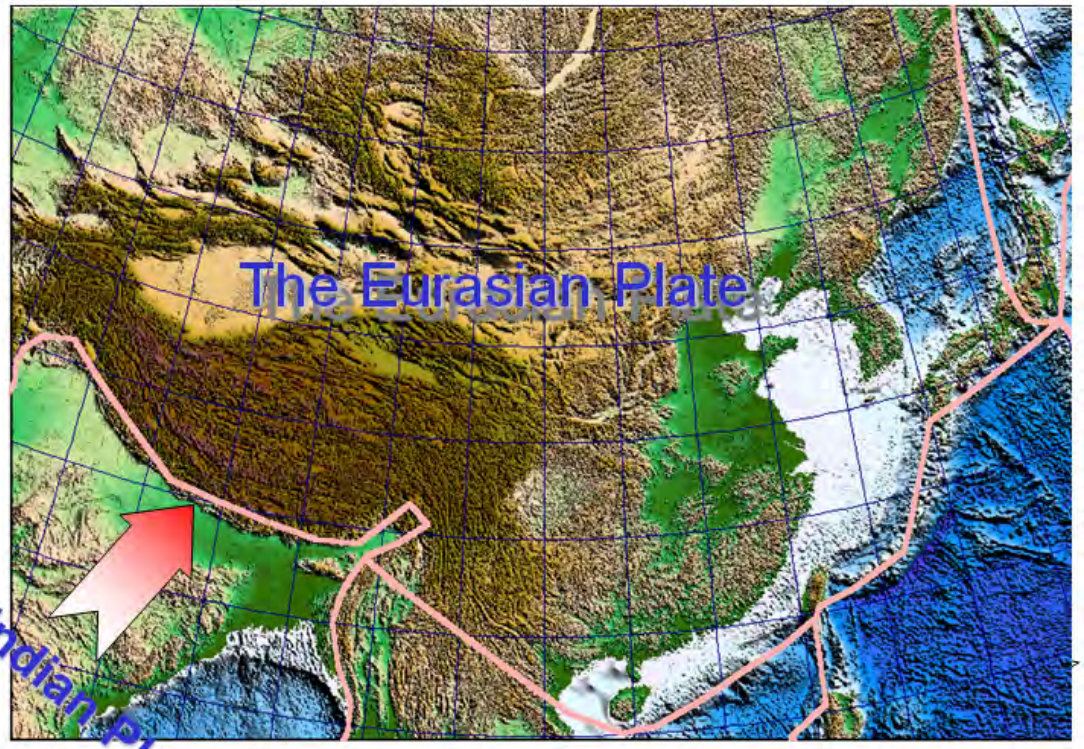
Indian Plate Movement

Indian Plate Movement

- It is currently moving northeast at 5 cm/yr (2) in/yr, while the Eurasian Plate is moving north at only 2 cm/yr (0.8 in/yr)
- It has covered a distance of 2,000 to 3,000 km (1,200 to 1,900 mi) in last 55 million years
- It moves faster than any other known plate
- This is causing the Eurasian Plate to deform, and the Indian Plate to compress



The Cause of Sichuan Earthquake



The convergence of the two plates is broadly accommodated by the uplift of the Asian highlands.

Xianshuihe Fault

Longmenshan Fault

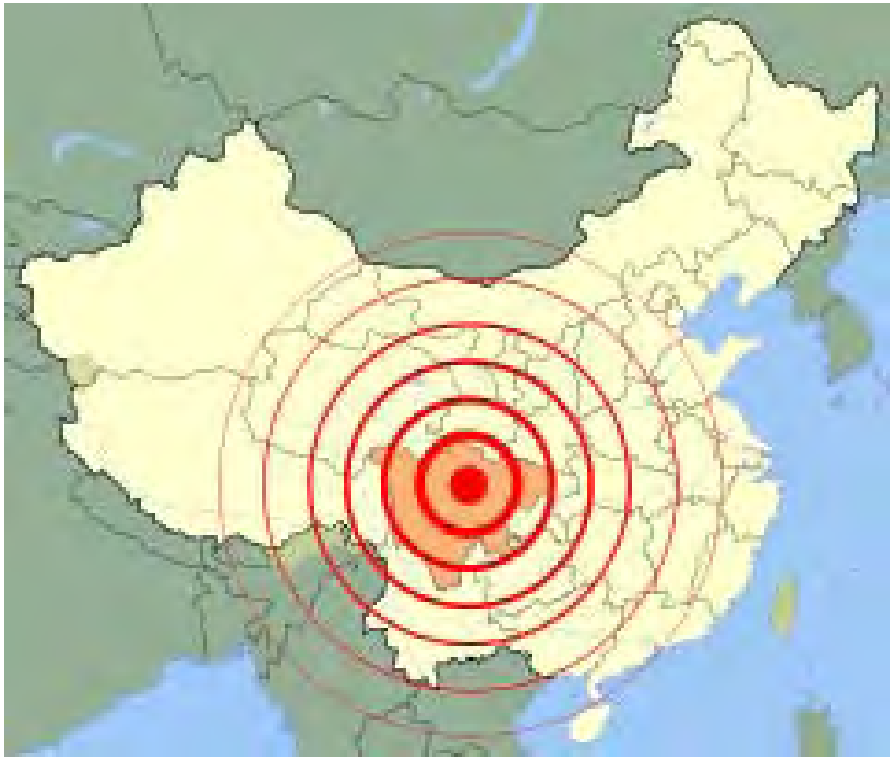
Yangtze Plate

Earthquakes happen frequently in Sichuan Province. Released energy had been dissipated by Xianshuihe Fault.

Longmenshan Fault, which was thought to be inactive, experienced a large movement on May 12, 2008.

The extent of the earthquake and after shock-affected areas lies north-east, along the Longmenshan Fault.

2008 Sichuan earthquake



Date: May 12, 2008

Magnitude: 8.0

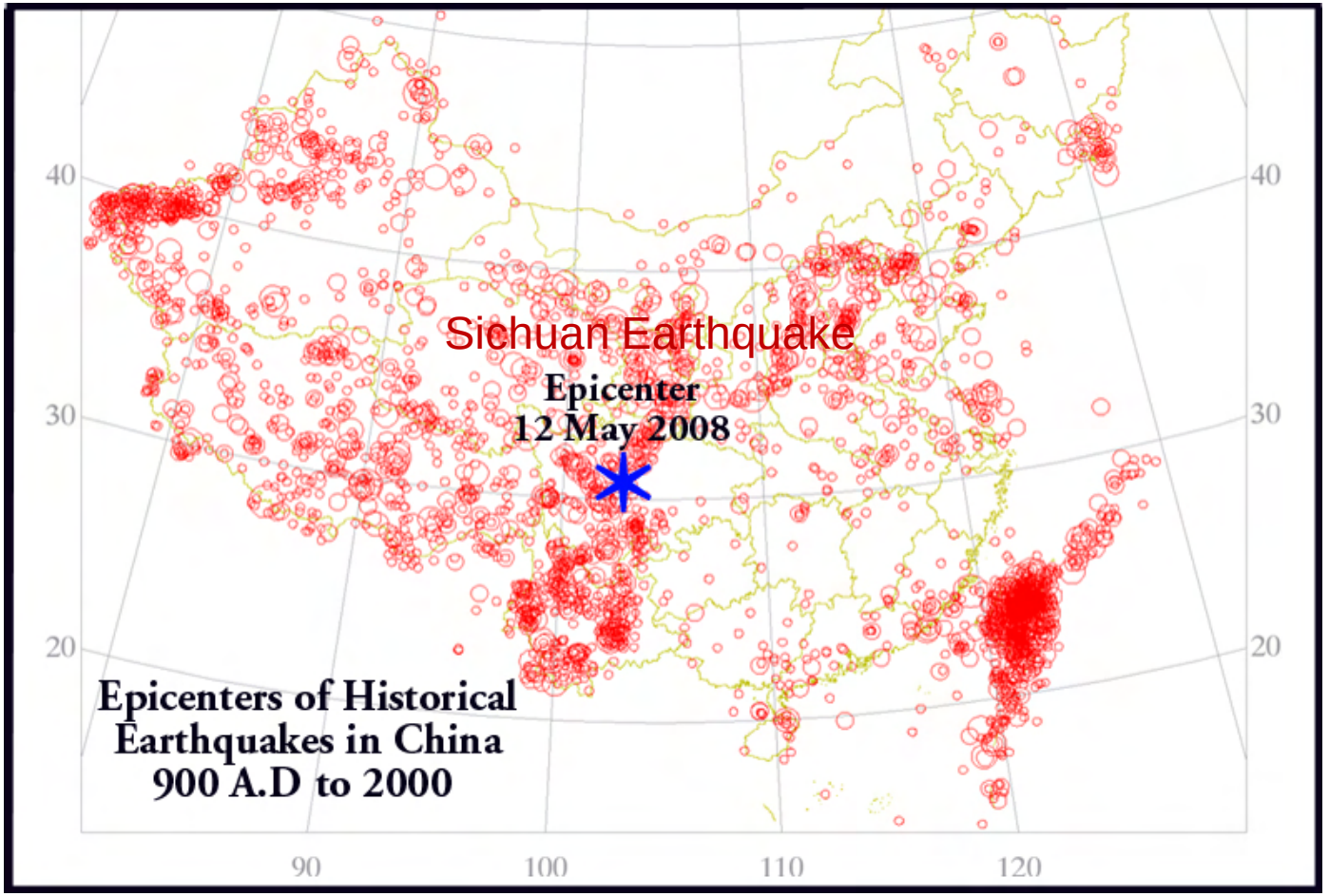
Hypocentre Depth: 19 kM

Epicentre: Wenchuan County (Sichuan Province)

Aftershocks: over 7,000 total aftershocks

Official figures (as of July 6, 2008 12:00 CST) state that 69,197 are confirmed dead, and 374,176 injured, with 18,340 listed as missing.

Earthquakes in China



Sichuan Earthquake

High frequency content, large (a,v,d) magnitude, shallow hypocenter, and near epicenter leads to serious earthquake damage

Sichuan earthquake aftermath

How are earthquakes measured?

- M-Scale Energy Release (Richter Scale)
- I-Scale Human Perception (MM-Modified Mercalli)
- a-Ground acceleration (Zones)

Relationship

$$I = 1.44M + F(R)$$

F is a decreasing function of *R*.

Empirical Relations

$$a = 1230\, e^{0.8M}\, \left(R + 25\right)^{-2}$$

$$\nu = 15\, e^{M}\, \left(R + 0.17\, e^{0.59M}\right)^{-1.7}$$

$$\frac{ad}{\nu^2} = 1 + \frac{400}{R^{0.6}}$$

Here a, v and d are in cm/sec^2, cm/sec and cm

Practical Interest

$$\frac{ad}{\nu^2} = 5\, to\, 15$$

Tri-partite Graph for Sichuan Earthquake

Ground Motion Response Spectrum

According to empirical relations:

$$a = 1230e^{0.8M}(R+25)^{-2} = 1230e^{0.8\times 8.0}(80+25)^{-2} = 67.14 cm/\sec^2$$

$$v = 15e^{M}(R+0.17e^{0.59M})^{-1.7} = 15e^{8.0}(80+0.17e^{0.59\times 8.0})^{-1.7} = 18.09 cm/\sec$$

Practical interest $$d = \frac{6v^2}{a} = \frac{6\times 18.09^2}{67.14} = 29.24 cm$$

SDF response spectrum

Using the form "spectrum amplification factors for horizontal elastic response",

Damp = 5%

One Sigma (84.1%)

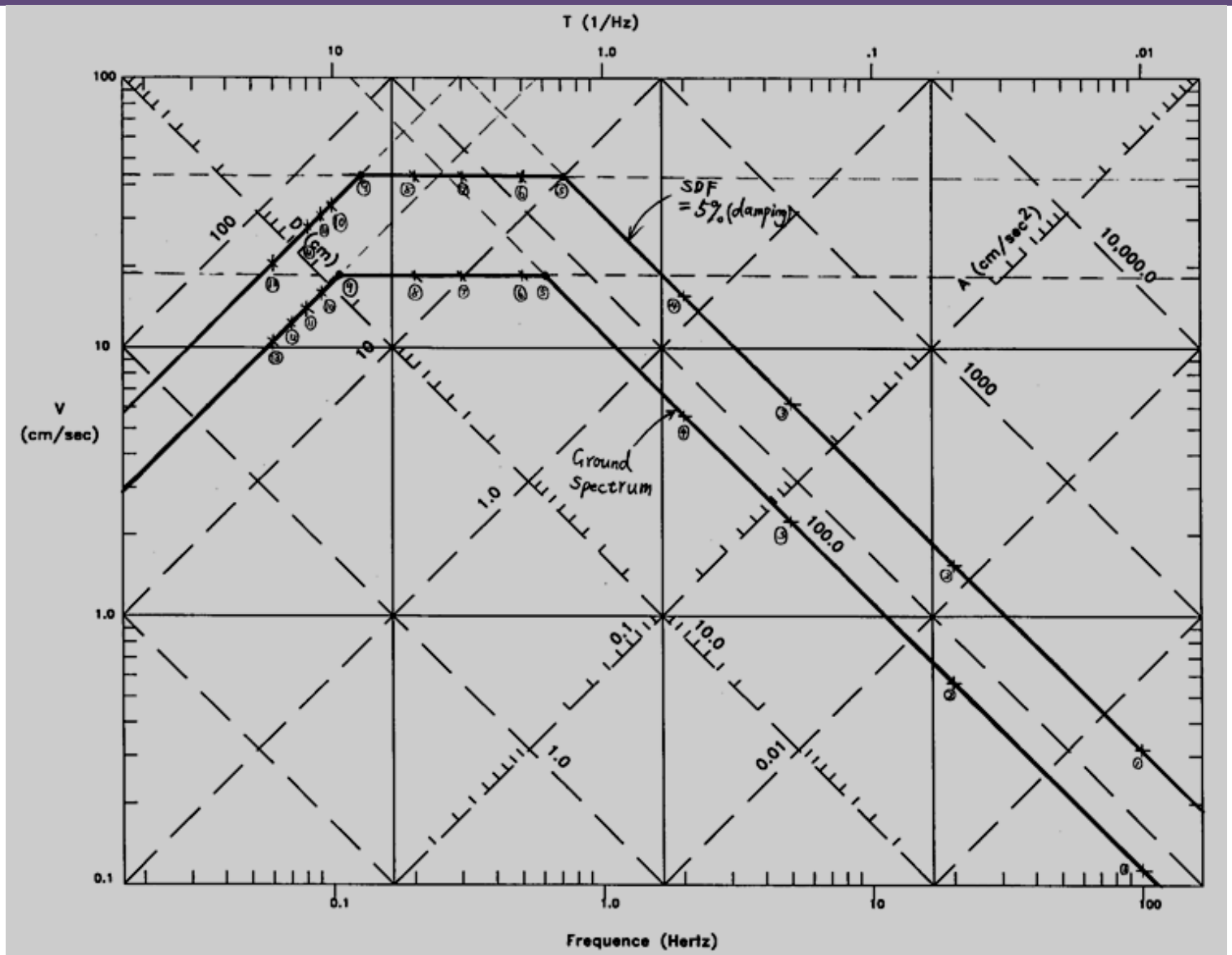
→

a = 2.71×67.14 = 181.95 cm/sec^2

v = 2.30×18.09 = 41.61 cm/sec

d = 2.01×29.24 = 58.77 cm

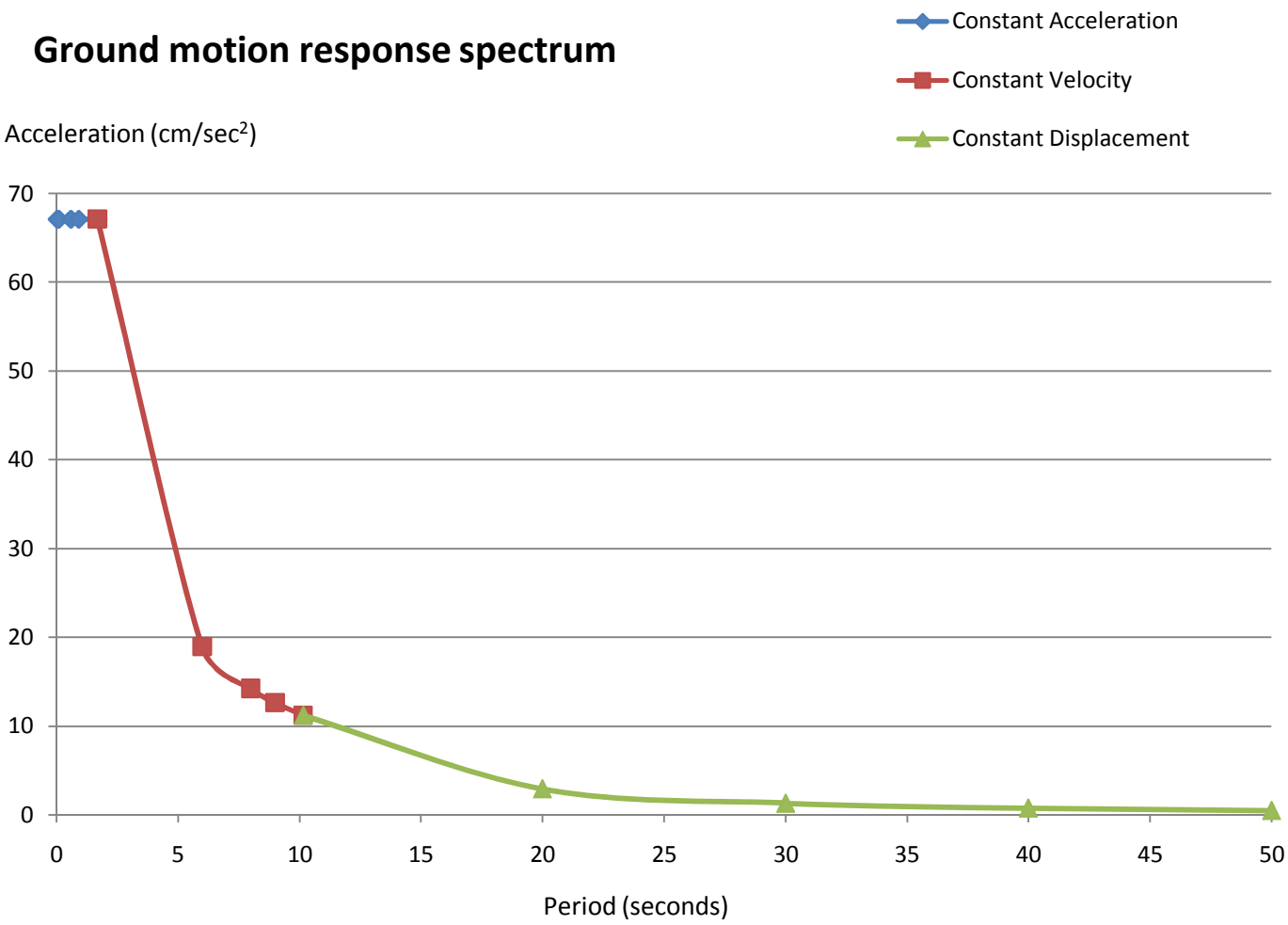
Tripartite Graph of Sichuan Earthquake



Formation of the Response Spectrum for Sichuan Earthquake

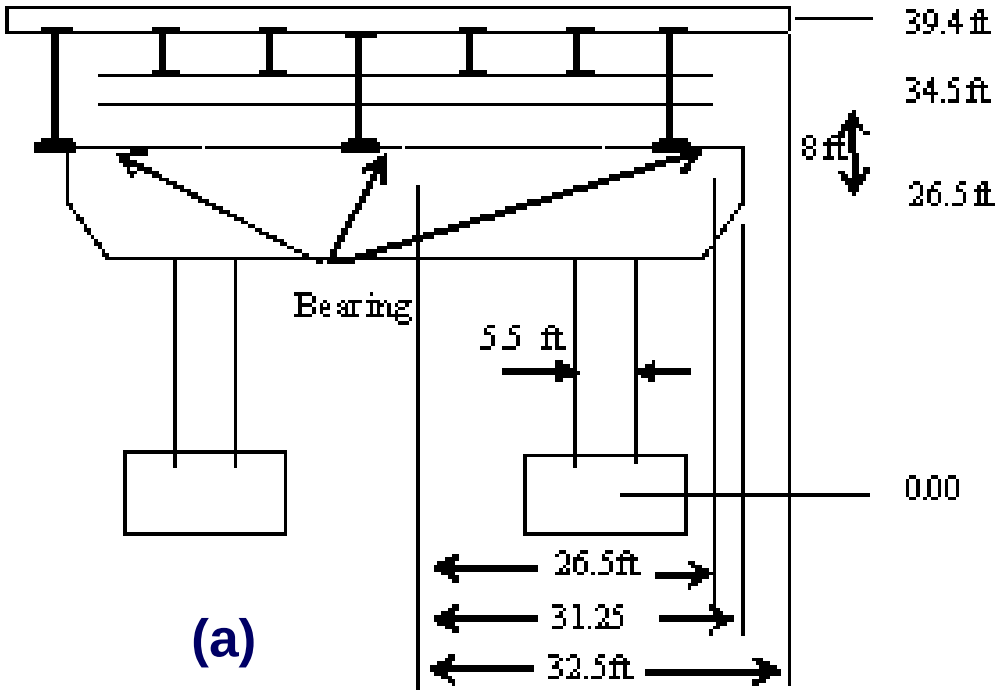
No.	Period (s)	A (cm/s2)	A (fraction of g)
1	0.01	67.14	0.7
2	0.09	67.14	0.7
3	0.6	67.14	0.7
4	0.9	67.14	0.7
5	1.69	67.14	0.7
6	6	18.94	0.2
7	8	14.21	0.1
8	9	12.63	0.1
9	10.16	11.19	0.1
10	20	2.89	0.0
11	30	1.28	0.0
12	40	0.72	0.0
13	50	0.46	0.0

Ground Motion Response Spectrum

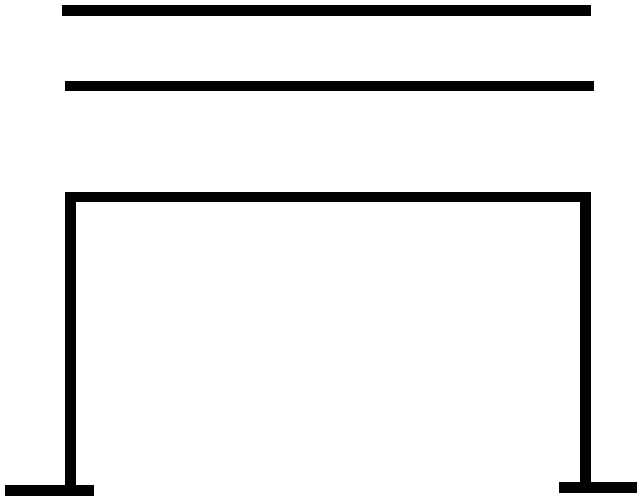


Portage Creek Bridge, Victoria, B.C

Portage Creek Bridge, British Columbia



(a)

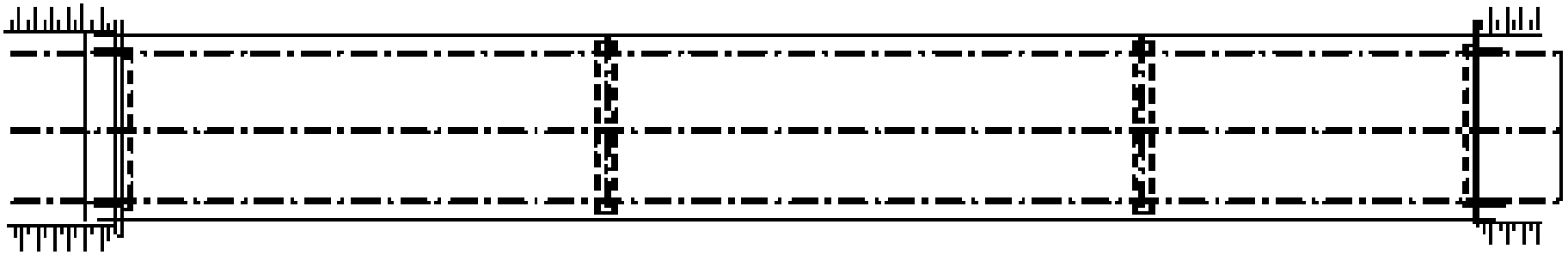


(b)

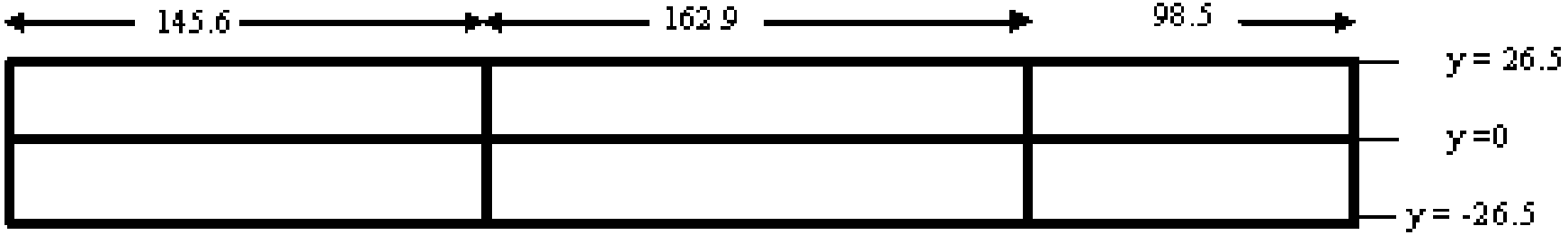
(a) Pier No. 1 – Portage Creek Bridge (McKenzie Overpass)

(b) Pier No. 1 – Simplified Geometry

Portage Creek Bridge, British Columbia

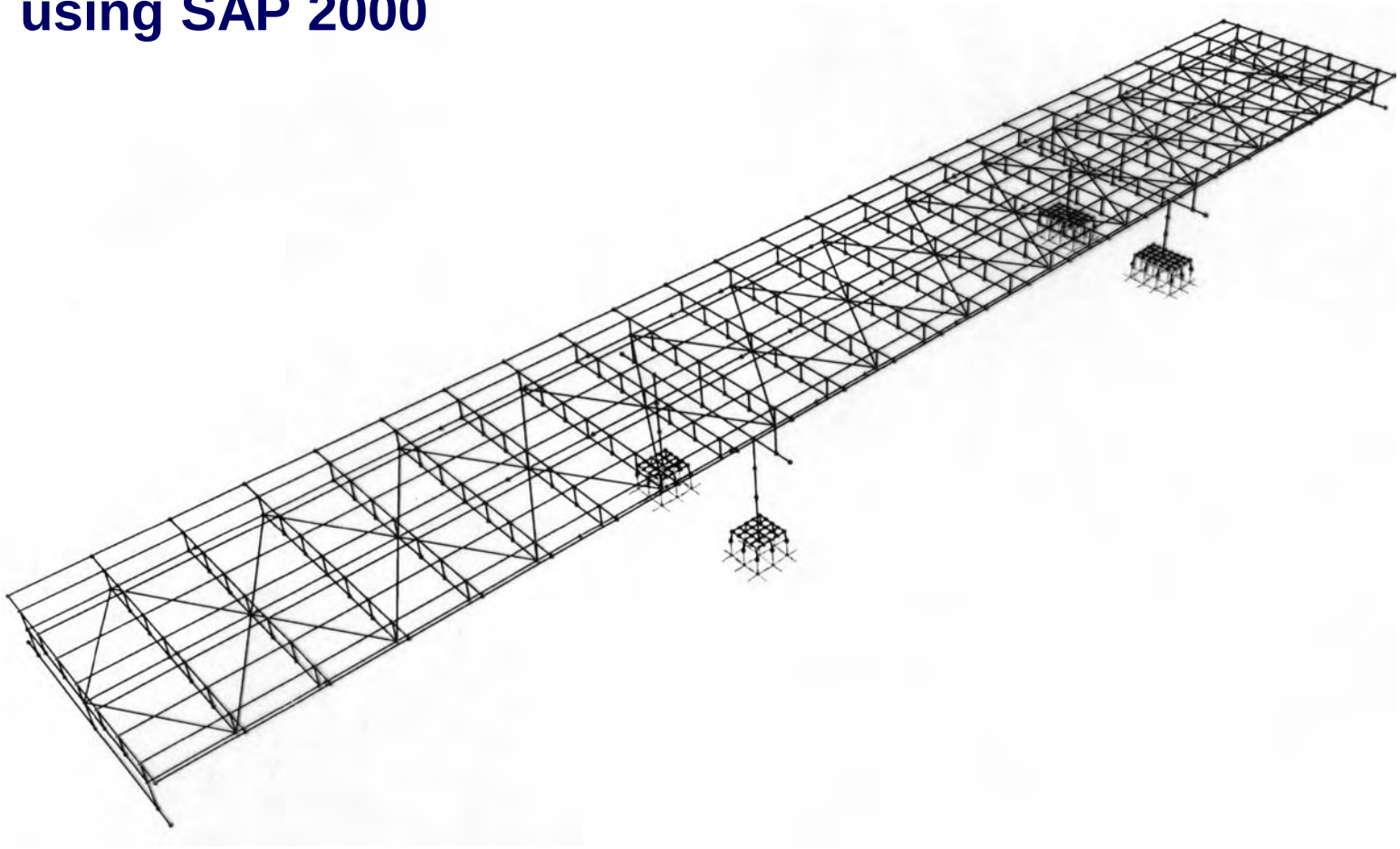


(a) Plan of Portage Creek Bridge (McKenzie Overpass)

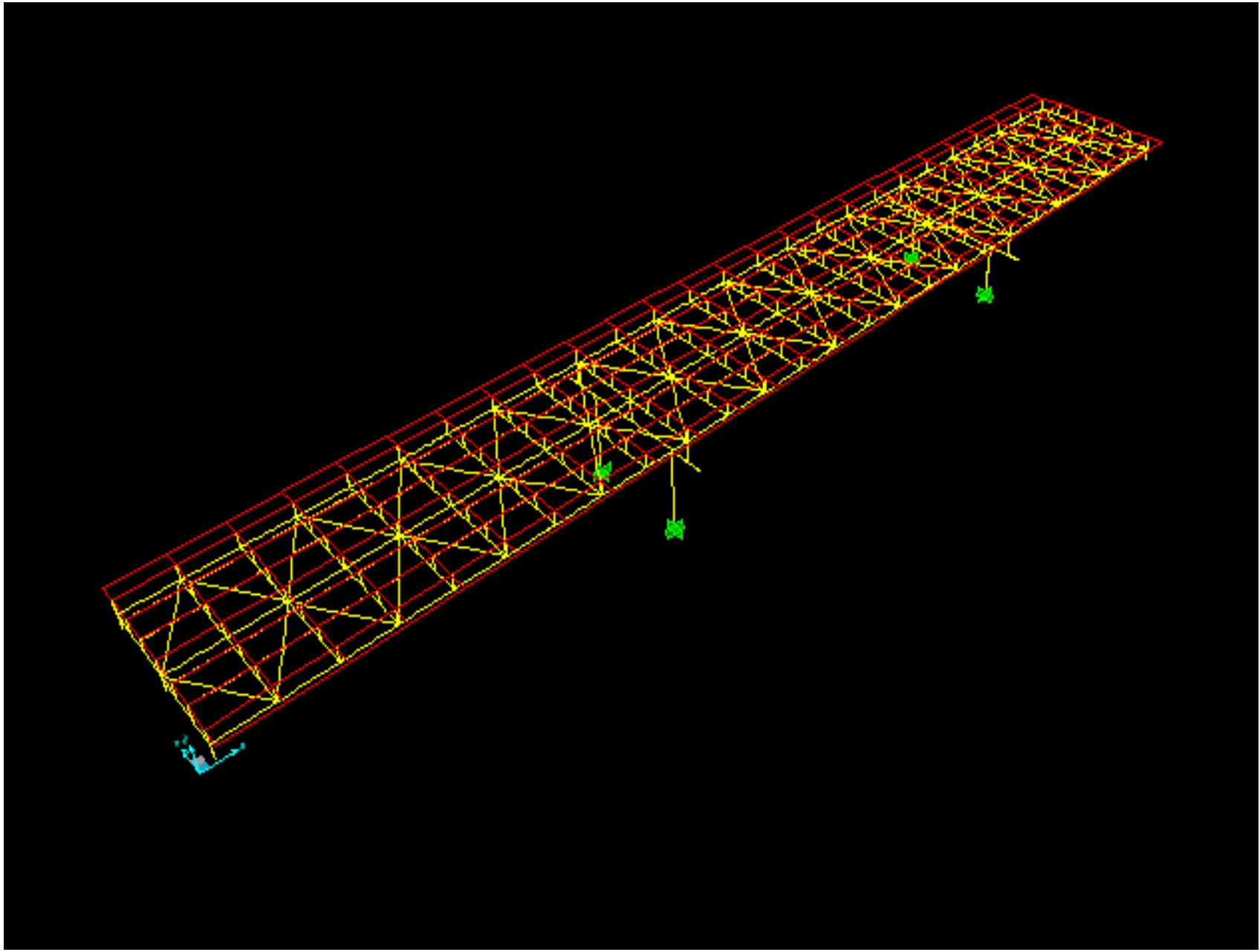


(b) Simplified Geometry of Portage Creek Bridge

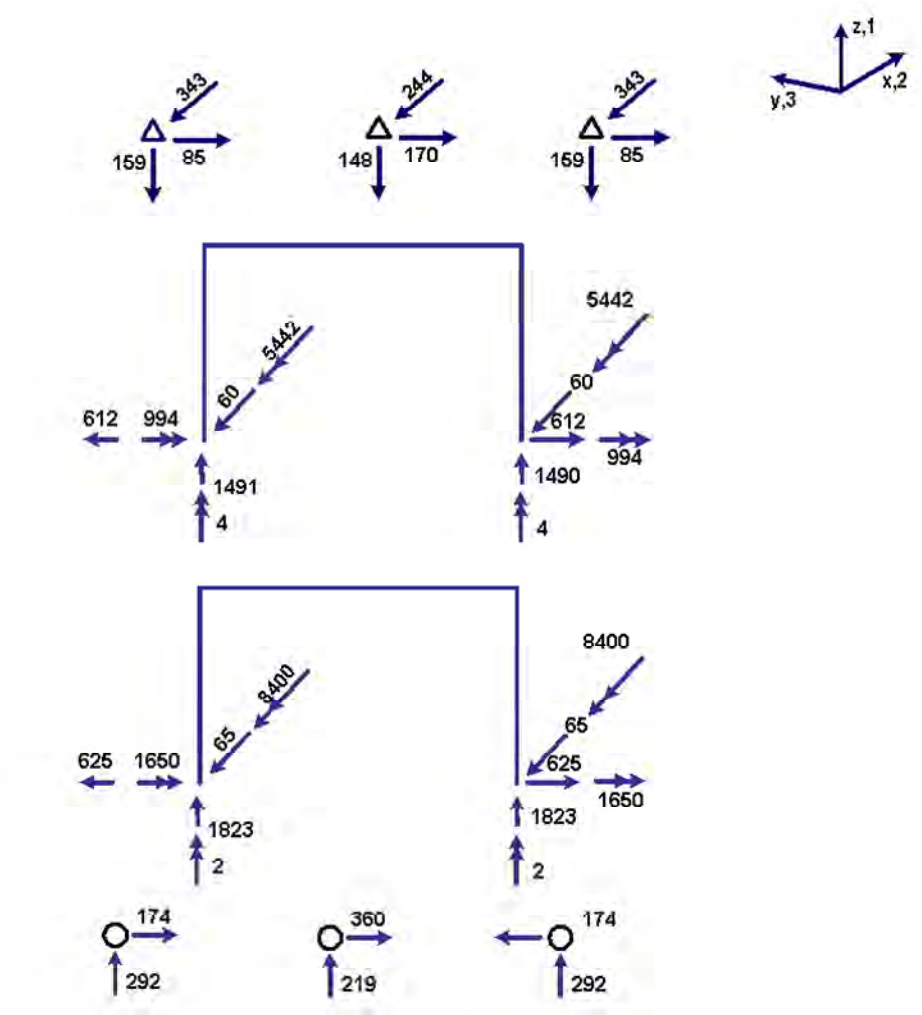
Finite Element Analysis using SAP 2000



Portage Creek Bridge



Portage Creek Bridge, British Columbia



Elastic response from SAP 2000 at the abutments and piers.

Measure Earthquakes

M-Scale	Energy Release	Richter
MM-Scale	Human Perception	Modified Mercallis
a-acceleration	Zones	Measured

All three are related to each other.

Sichuan Earthquake - May 12, 2008

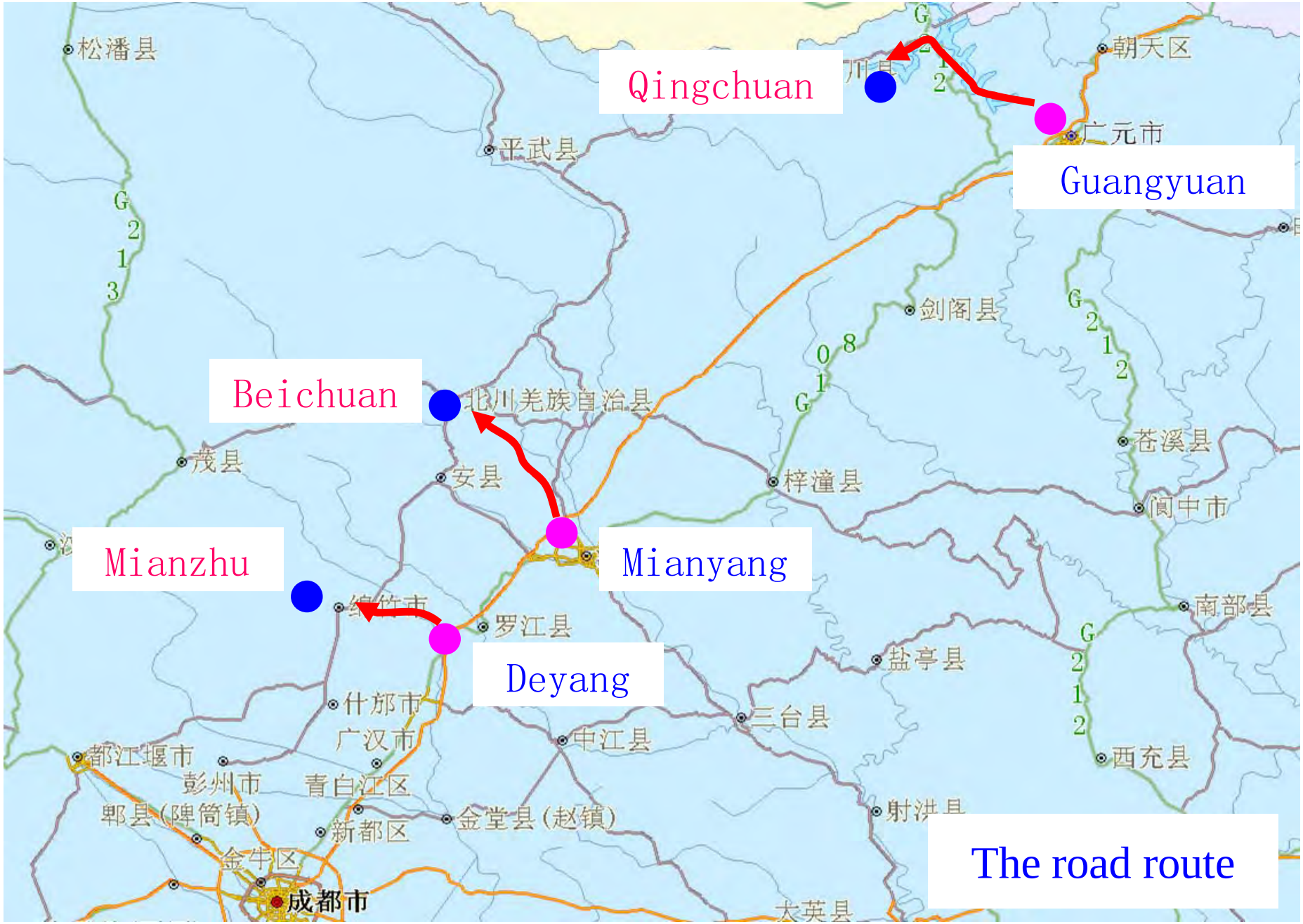
Richter Magnitude - M	8.0
MM-Scale	XI
Acceleration- a	0.7g

Provided by the Dean of Engineering, Hunan University, Changsha, China - Professor Yan Xiao, Dr. Eng.

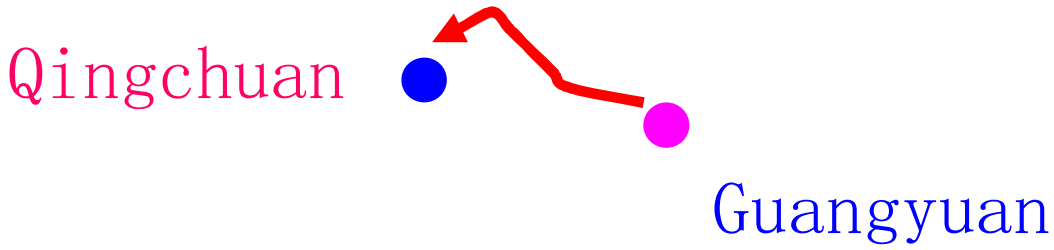
Seismic Intensity Scale

Intensity	Effects
1	People do not feel any Earth movement.
2	A few people might notice movement if they are at rest and/or on the upper floors of tall buildings.
3	Many people indoors feel movement. Hanging objects swing back and forth. People outdoors might not realize that an earthquake is occurring.
4	Most people indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. The earthquake feels like a heavy truck hitting the walls. A few people outdoors may feel movement. Parked cars rock.
5	Almost everyone feels movement. Sleeping people are awakened. Doors swing open or close. Dishes are broken. Pictures on the wall move. Small objects move or are turned over. Trees might shake. Liquids might spill out of open containers.
6	Everyone feels movement. People have trouble walking. Objects fall from shelves. Pictures fall off walls. Furniture moves. Plaster in walls might crack. Trees and bushes shake. Damage is slight in poorly built buildings. No structural damage.
7	People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
8	Drivers have trouble steering. Houses that are not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Tree branches break. Hillsides might crack if the ground is wet. Water levels in wells might change.
9	Well-built buildings suffer considerable damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.
10	Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas. Railroad tracks are bent slightly.
11	**Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed. Railroad tracks are badly bent.**
12	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.


四川震情动态示意图
This symbol indicates severe damage
剑阁县
北川县
江油市
茂县
安县
梓潼县
G317
理县
汶川县
涪城区
绵阳市
绵竹市
罗江县
盐亭县
什邡市
德阳市
三台县
都江堰市
彭州市
中江县
广汉市
震中
射洪县
新都县
金堂县
郫县
成都
大邑县
大英县
Epicenter


Qingchuan
Guangyuan
Beichuan
Mianzhu
Mianyang
Deyang
The road route
松潘县
平武县
朝天区
广元市
剑阁县
苍溪县
阆中市
茂县
安县
梓潼县
北川羌族自治县
南部县
罗江县
盐亭县
什邡市
广汉市
三台县
中江县
西充县
都江堰市
彭州市
青白江区
郫县(犀浦镇)
新都区
金堂县(赵镇)
金牛区
成都市
大英县
G212
G108
G213

Cities in the Damage Zone



Many bridges span the waters between Quingchuan and Guangyuan. The damage to several bridges are discussed in the following slides.

State road 212 from Baolun to Shazhou


State road 212
Bailonghu Reservoir
Image © 2008 DigitalGlobe
© 2008 Europa Technologies


Ganxihe Bridge

Ganxihe Bridge

Damage to the abutment walls

Damage to the abutment walls

Damage to the abutment walls

Damage to deck


Baishui Bridge

Baishui Bridge

No visible damage middle arch

Crushing of concrete in spandrels

Movement of pylon

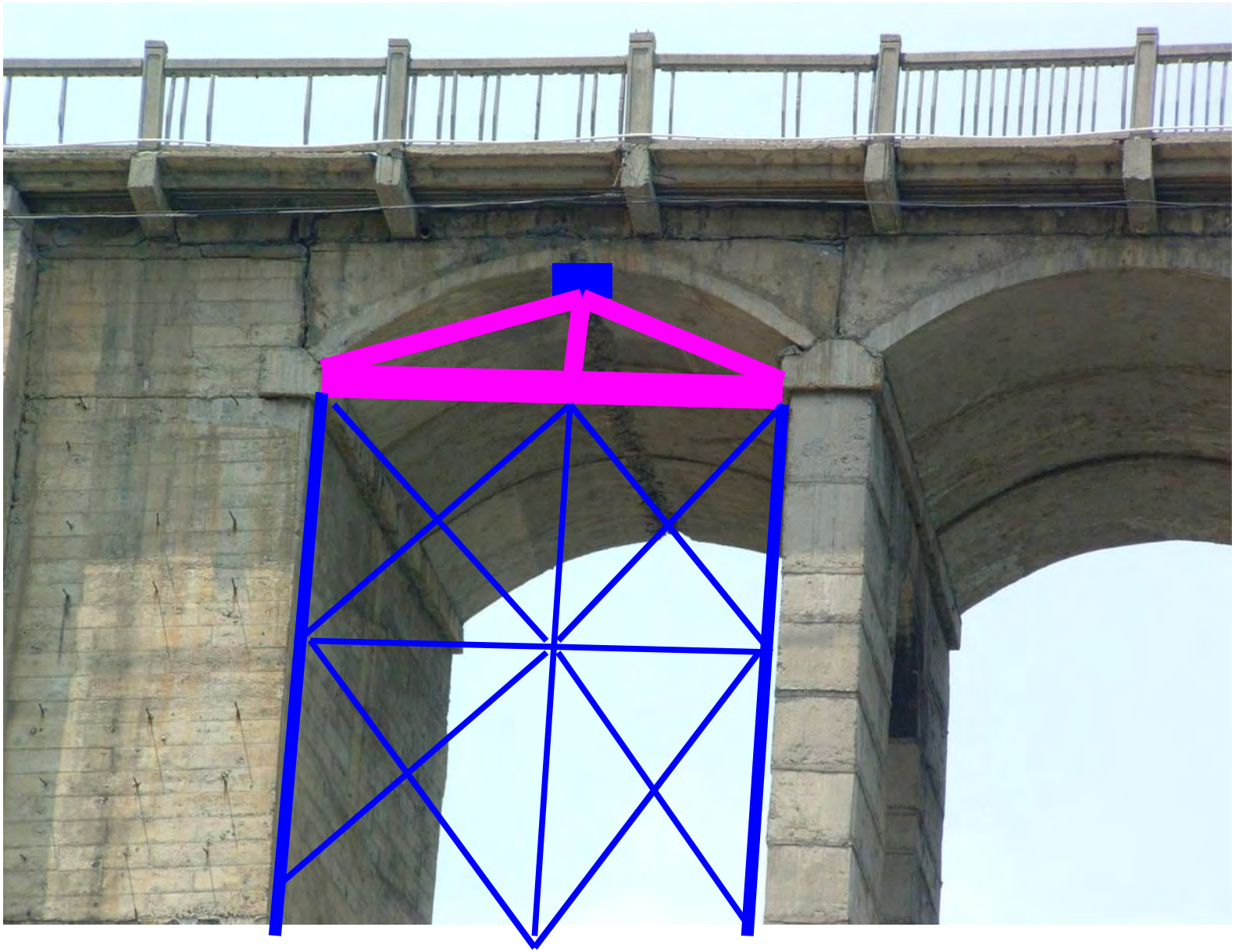
Crack in the deck

Crack in abutment

Reason for the Damage

This reinforced concrete bridge appears to have had no significant damage to its main spans. However, due to large longitudinal movement during the earthquake, the short interior arches close to the abutments including expansion joints, suffered a lot of damage. Because of this, the bridge cannot be opened to traffic without major repairs.

Temporary Support for the Interior Arch




Jingtianba Bridge

Jingtianba Bridge

Two-span arch bridge (each span70m) collapsed closing provincial road 105

20m tall pier

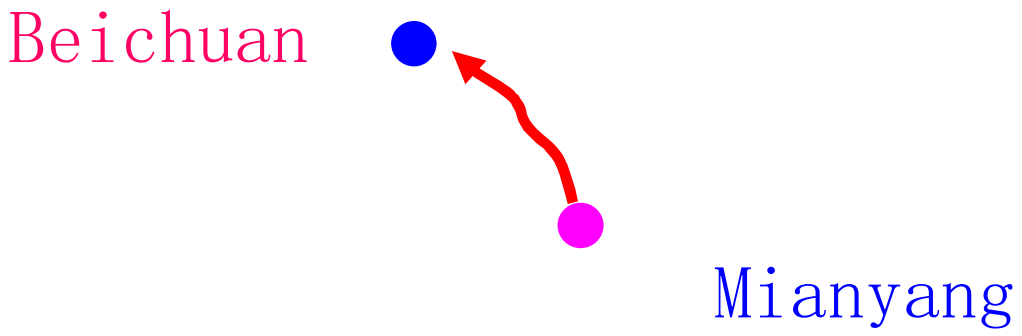
20m tall pier

Interim Measures

There are a number of solutions for the replacement of this bridge on a temporary basis, which include: a military pontoon bridge, some other kind of temporary bridge, as well as relocation of the road, which will eliminate the need for the bridge.

Currently, the relocation of the road seems to be the most favourable solution.

Cities in the Damage Zone



Bridges spanning the waters between Beichuan and Mianyang

Anzhou Bridge

Anzhou Bridge

This is a two span arch bridge showing damage to various of its components.

It is hoped the bridge can be repaired.

Bridge before damage

Damage to K-brace

Deck is still in good condition

Interim Measures

1. In spite of the damage, the bridge is still open to traffic, with the following restrictions: the speed limit was reduced; the gross vehicle weight was reduced; and the traffic was directed to travel on the center of the bridge.
2. The bridge is to be inspected frequently to make sure there is no further damage to any of its components.

Xiangyangchun Bridge

Xiangyangchun Bridge is a short two-span bridge located on a curve, showing damage to various components. No assessment has yet been made regarding required repairs.

Showing the bottom of the deck which consist of precast voided concrete box girders

Broken pier cap

Movement of the expansion joint

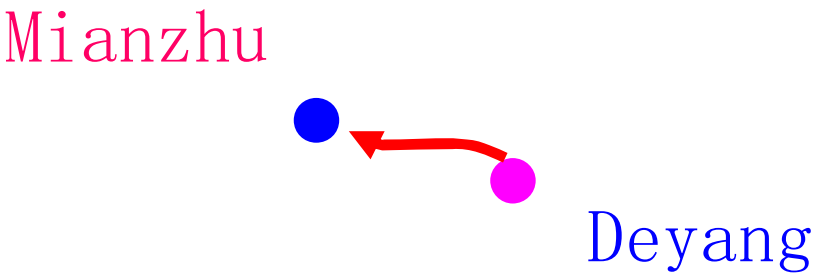
Horizontal crack and movement of the abutment wall

Barrier wall moved

Nanba bridge under construction during earthquake

Collapsed girders

Cities in the Damage Zone



Bridges spanning the waters between Mianzhu and Deyang

Jinhua Bridge

Crack in abutment

Displacement between the bridge deck and road surface at an expansion joint

Reason for the Damage

The bridge survived the earthquake reasonably well. Most of the damage appears to have been caused by large horizontal forces as is evidenced by the damage to the short interior arch columns.

Wudu Mawei River Bridge

This bridge survived the earthquake very well. Damage was concentrated at the abutments, with one abutment having a movement of approximately 450 mm.

Bearing of one girder

Girder movement on the top of the pier cap

Reason for the Damage

Problem with rubber bearing was observed on some of the bridges. It appears that rubber bearings do not offer enough restraint to prevent girders from falling off the bearings during the sudden movements caused by the earthquake.

Mianzhu Lujiaoyan Bridge

Another example of damage as a result of sudden movements experienced during earthquakes

Guantong Bridge

Masonry arch bridge

Showing damage to the deck and railing on one side of the solid center of the bridge

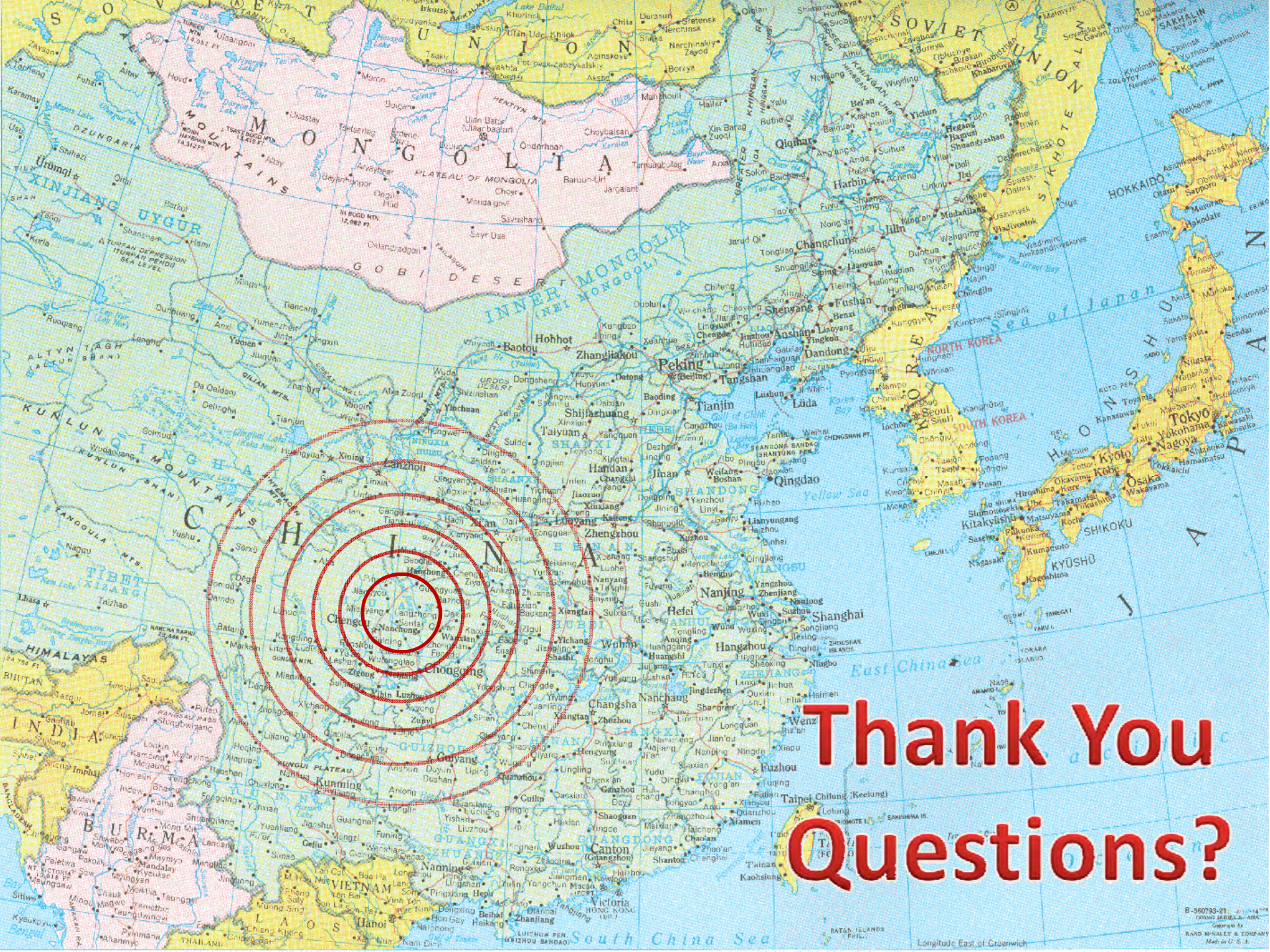
Showing cracks at the bottom of the arch

Cracks at the top of the most interior arch

Reason for the Damage

Cracks at the bottom of the arch were caused by repeated back and forth horizontal movement during the earthquake.

Cracks at the top of the most interior arch were caused by the same movement, but were exaggerated by the resistance of the solid center main arch section.


Thank You
Questions?