OBSERVATIONS AFTER 5/12/2008 WENCHUAN EARTHQUAKE BASED ON FIELD RECONNAISSANCE FROM 7/4/2008 TO 7/7/2008

Khalid M. Mosalam, PhD, PE mosalam@ce.berkeley.edu
Professor and Vice Chair for Research and Technical Services
Dept. of Civil and Environmental Engineering
&
Nicholas Sitar, PhD, PEng sitar@ce.berkeley.edu
Professor and Director of the Earthquake Engineering Research Center

University of California, Berkeley, CA 94720-1710

Acknowledgements
Funding and logistical support were provided by:
Office of International Strategy Development, University of California Office of the President (UCOP);
Center for Information Technology Research in the Interest of Society (CITRIS), UC Berkeley;
Prof. Jian-hui Deng, Prof. Bixiong Li, Prof. Ping Guan, and Prof. Shijing Yan, Sichuan University, Chengdu, China;
Office of the President and International Office, Sichuan University, Chengdu, China

Outline

- Visited cities
- Dujiangyan and Zipingpu towns
- Yingxiu and Xuankou towns
- Hongkou town
- Hanwang town (Mianzhu city)
- Faulting and landslides
- Tunnels and retaining structures
- Materials and reconstruction
- Concluding remarks

Visited Cities

Dujiangyan & Zipingpu Towns

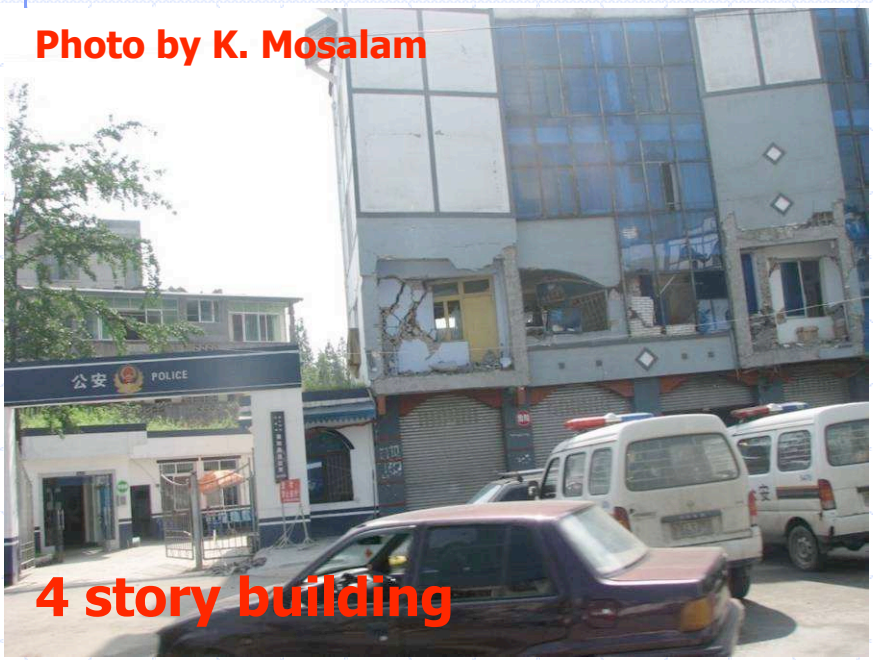
Outline

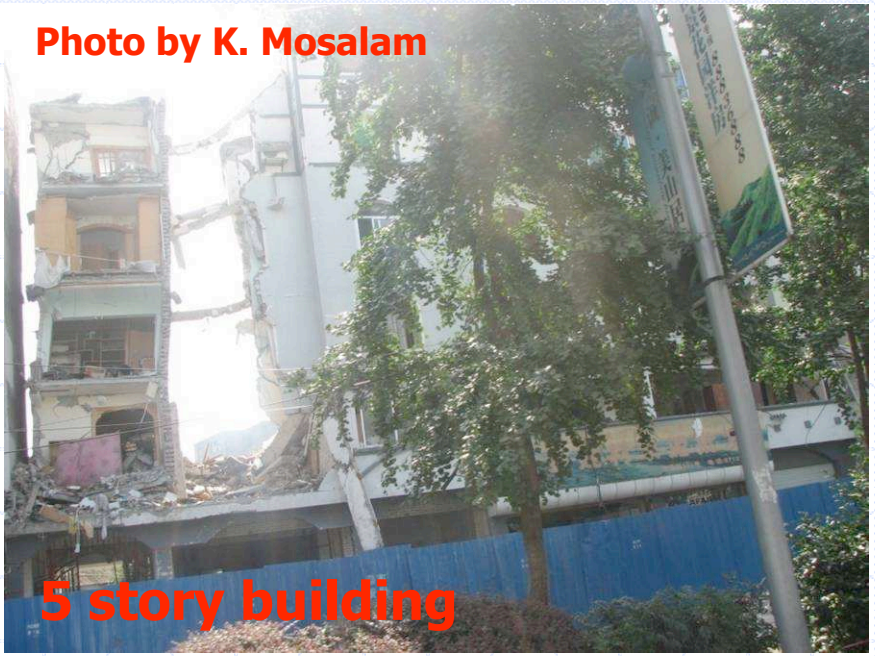
- Dujiangyan town
  - Good performance
  - Fair performance
  - Poor performance
- Zipingpu dam

Dujiangyan Town (Good Performance)

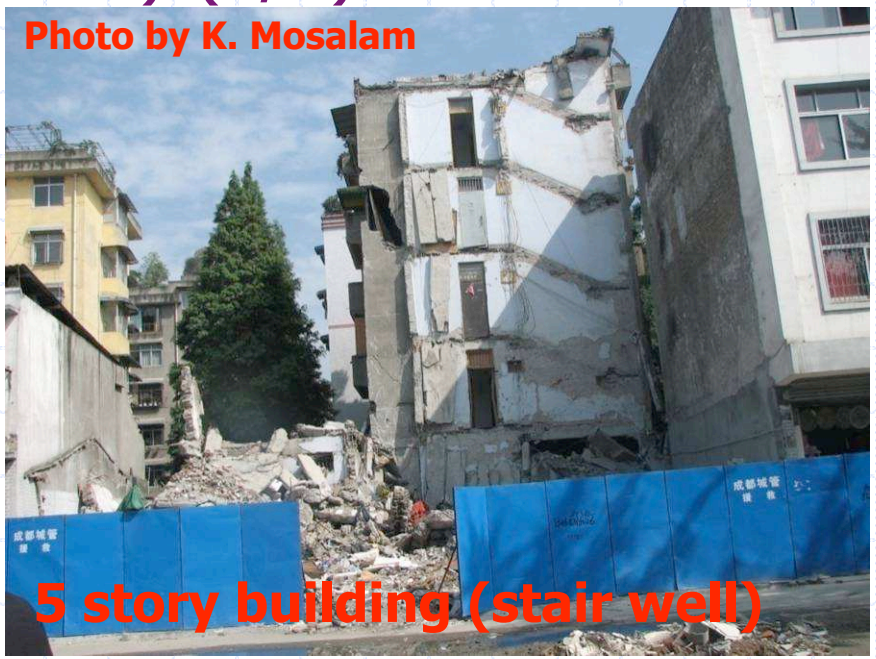
Dujiangyan Town (Fair Performance)

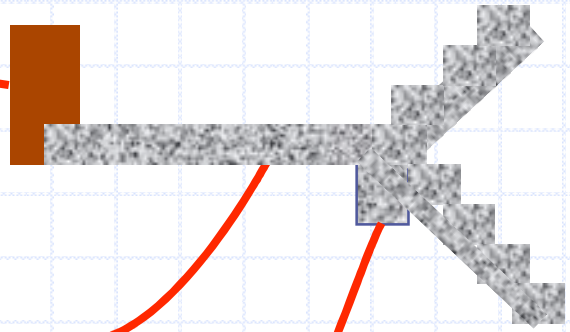
Dujiangyan Town (Poor Performance) (1/3)



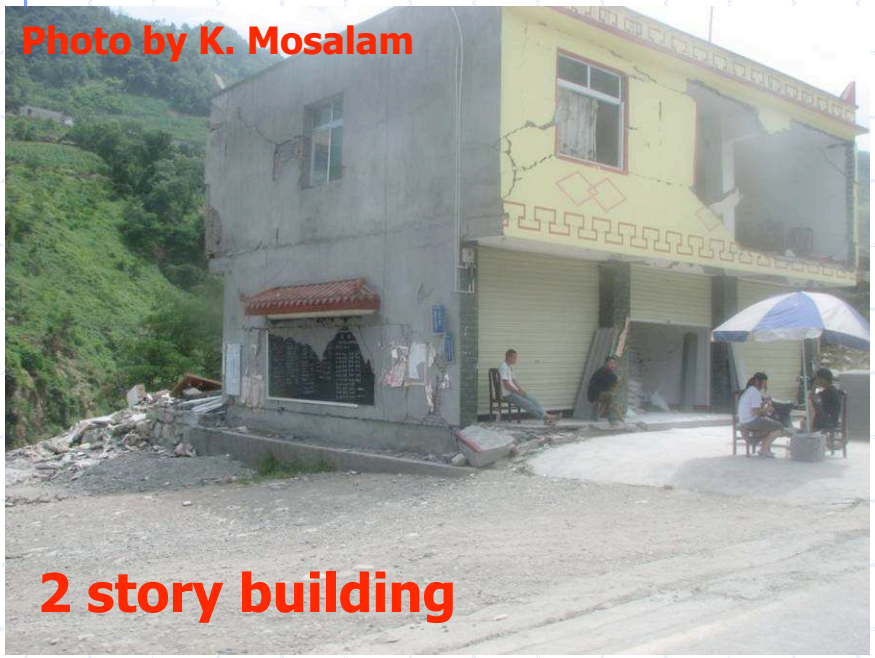


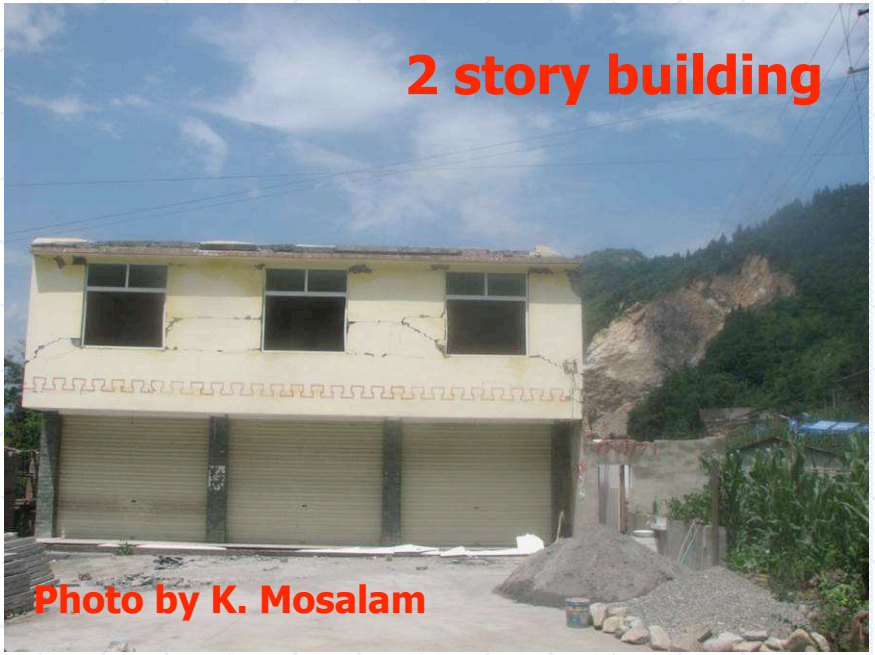
Stair Wells (Poor Performance) (2/3)



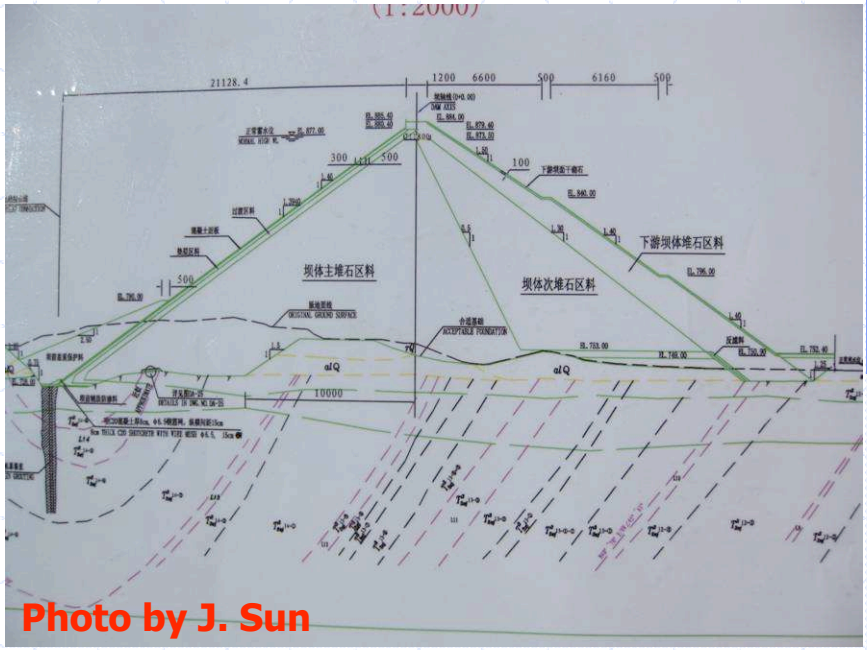


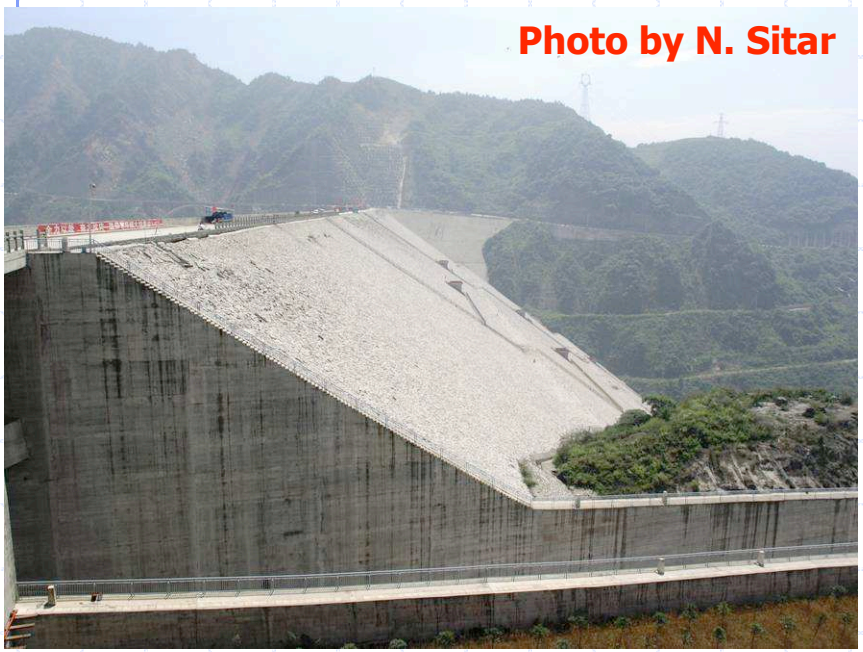
Dujiangyan Town (Poor Performance) (3/3)

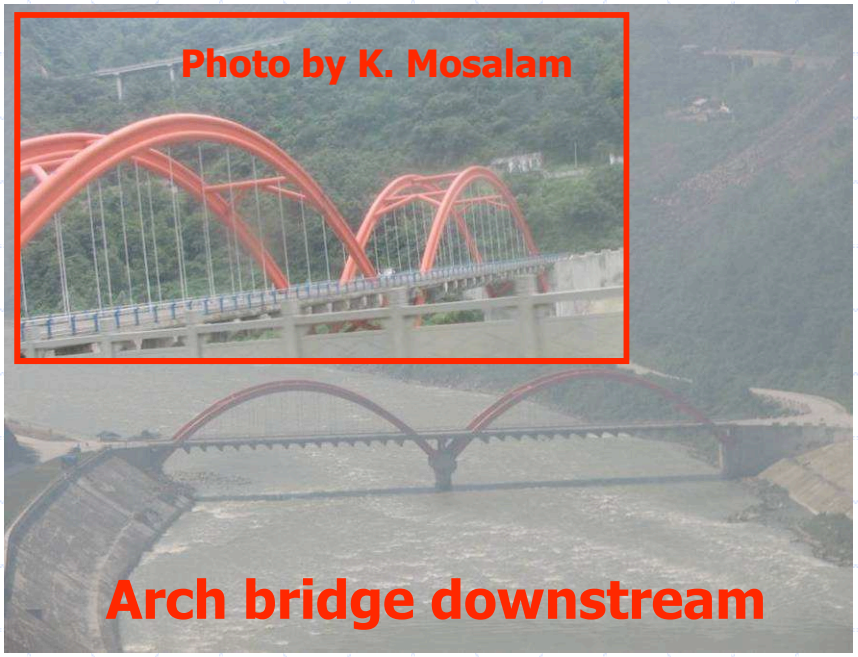




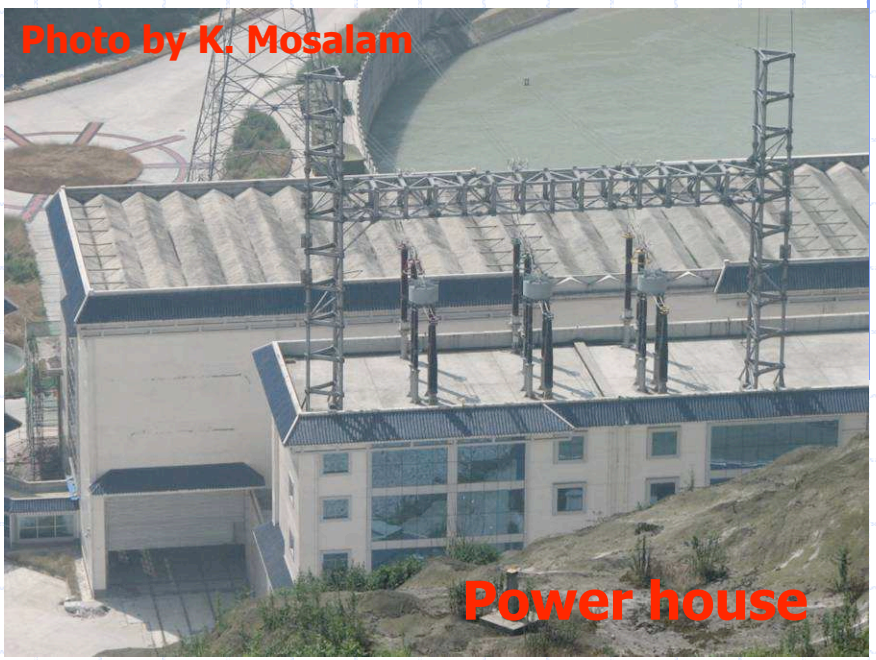
Zipingpu Dam (1/7)



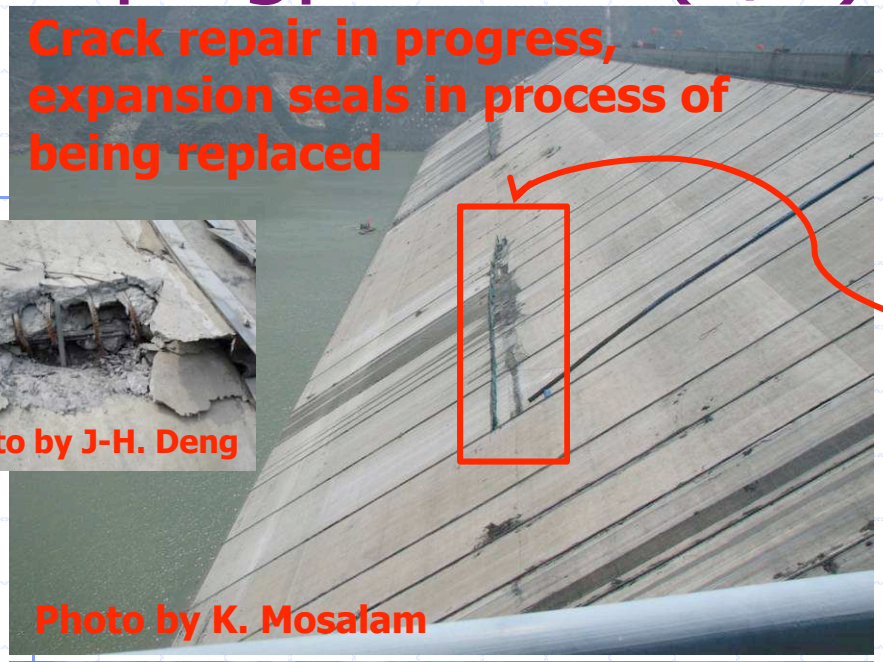


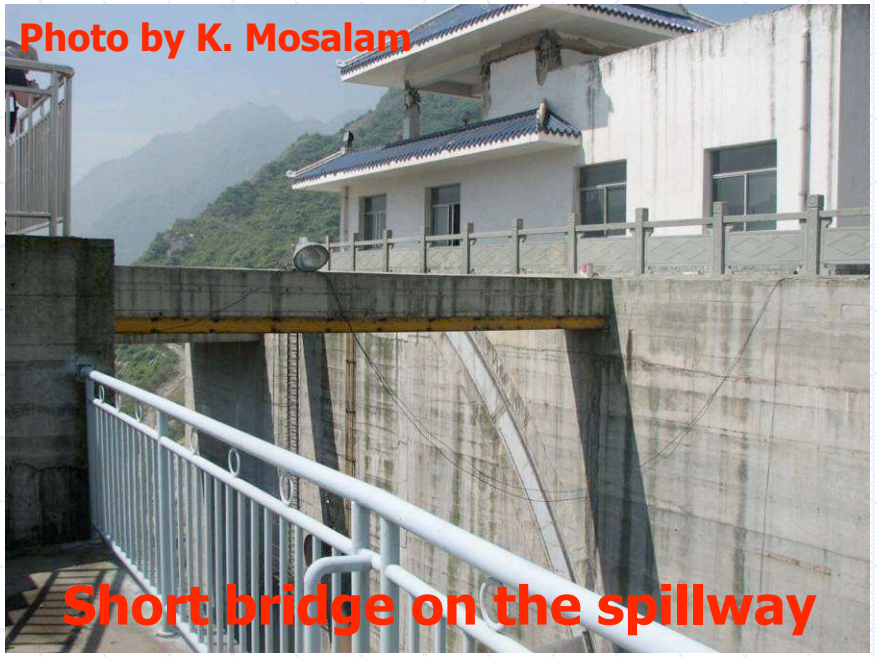


Zipingpu Dam (2/7)

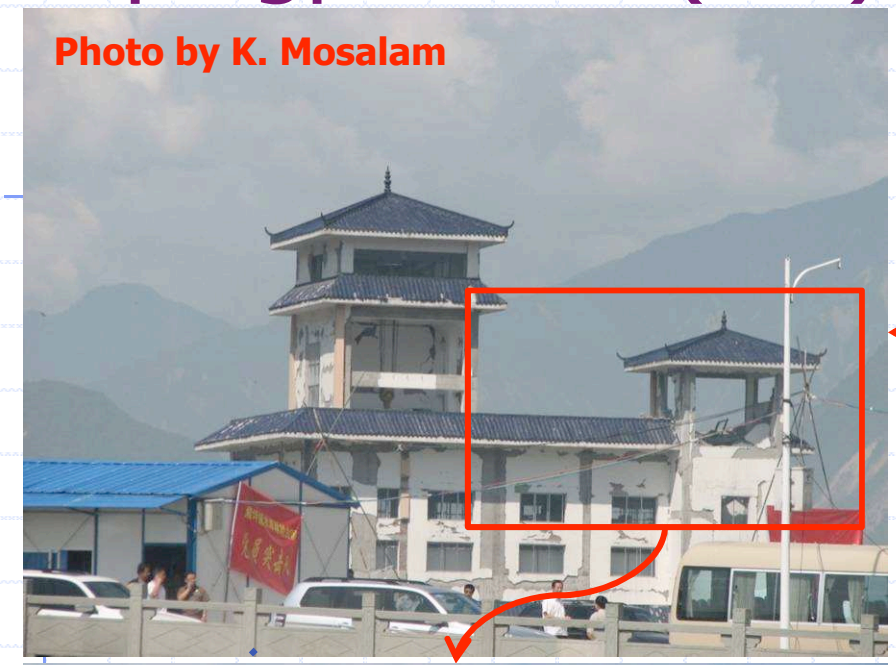


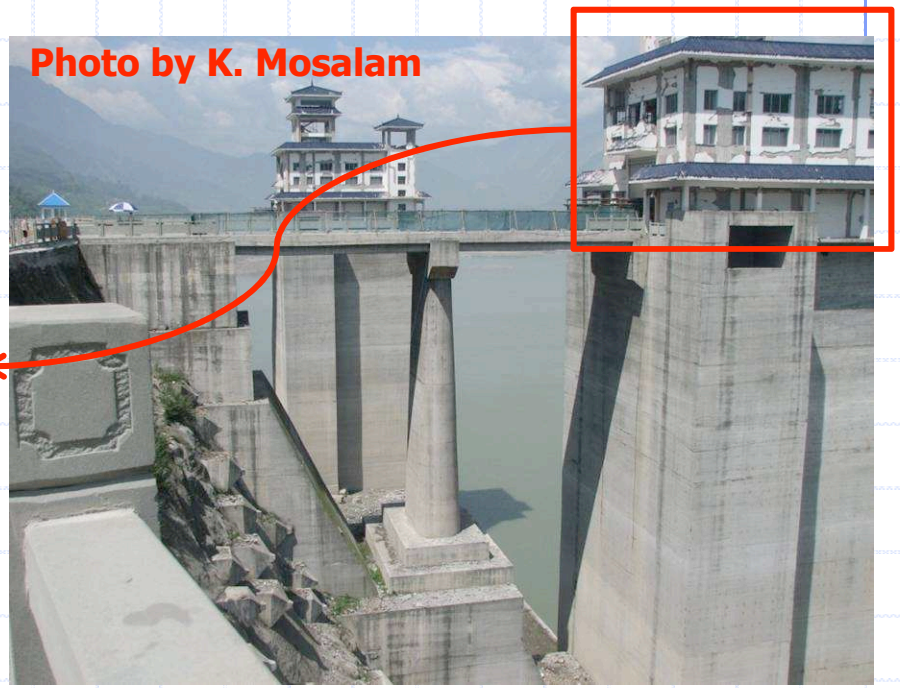
Zipingpu Dam (3/7)

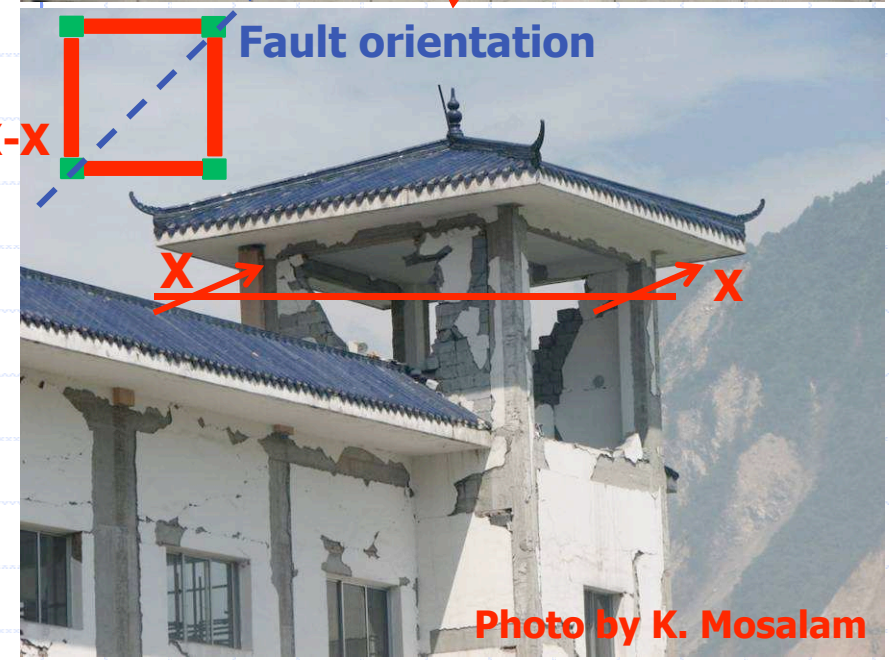




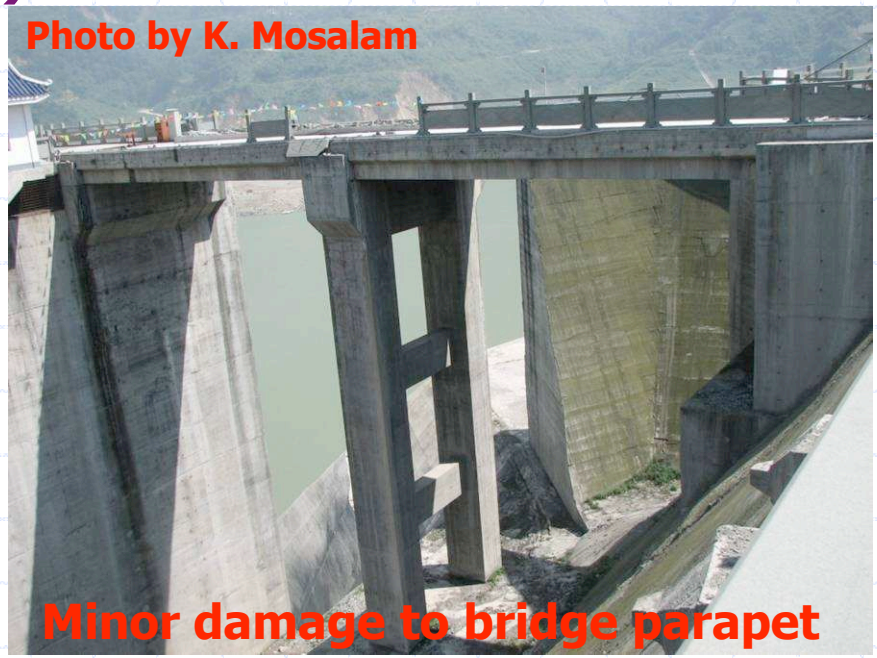
Zipingpu Dam (4/7)

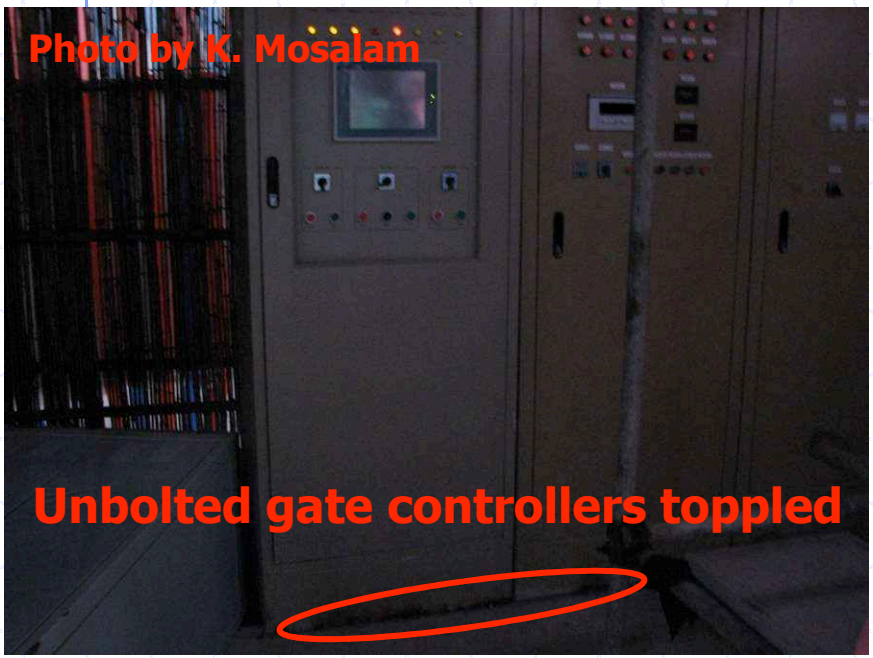


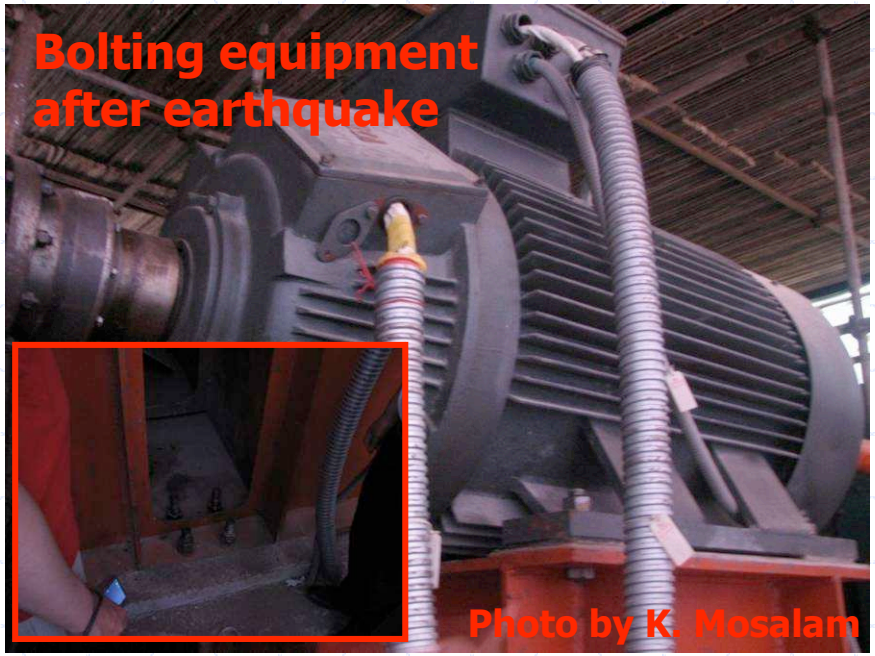




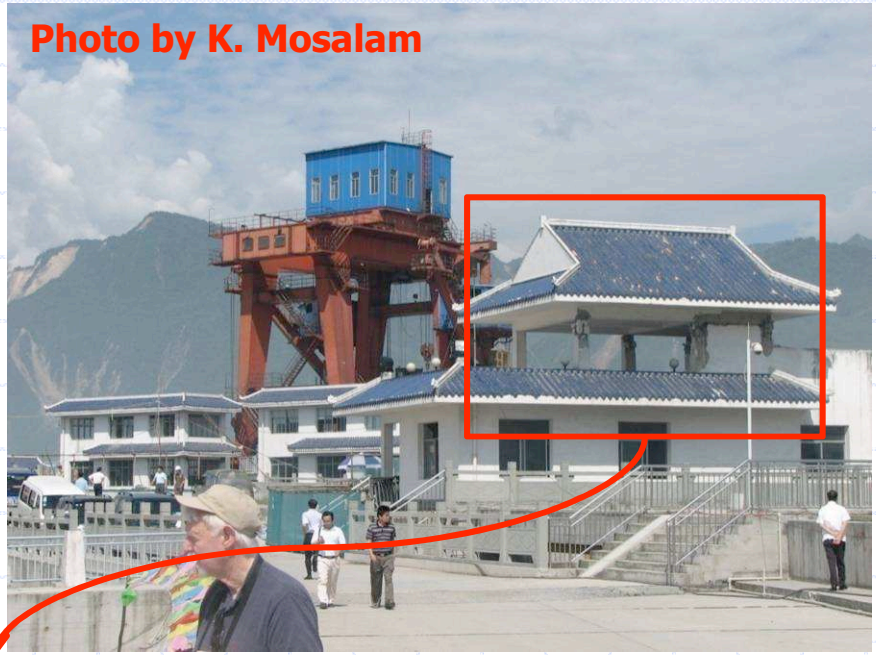
Zipingpu Dam (5/7)

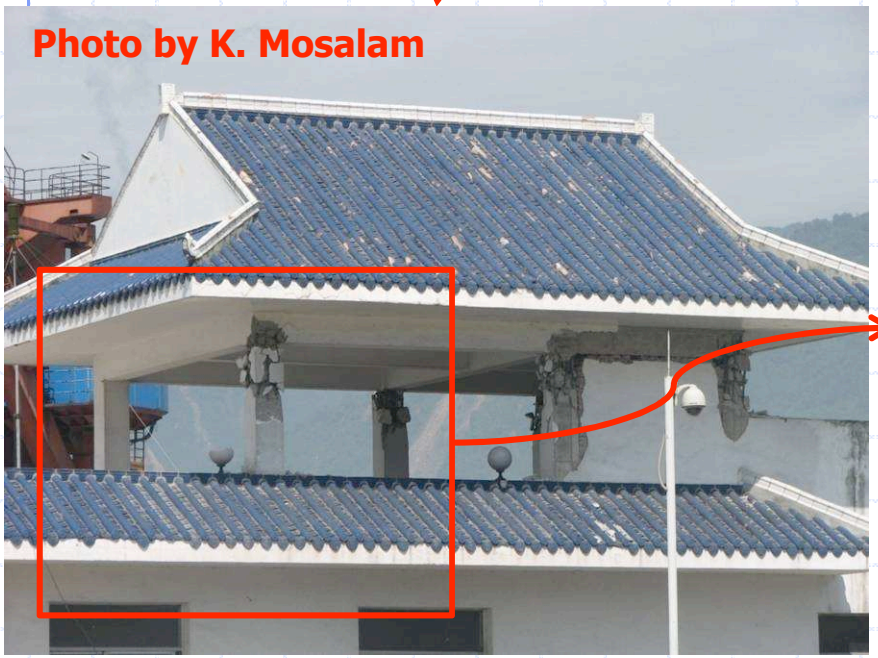




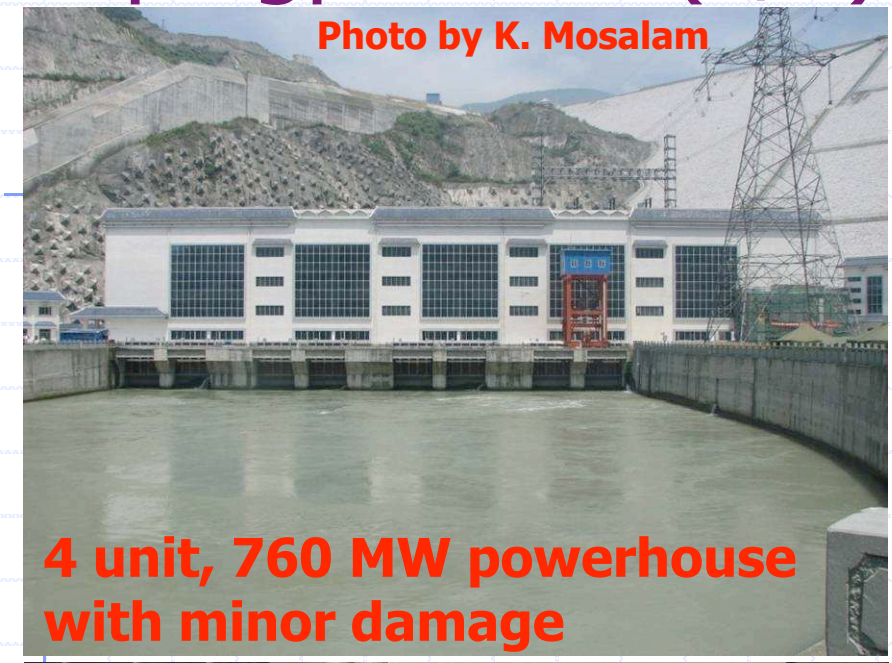


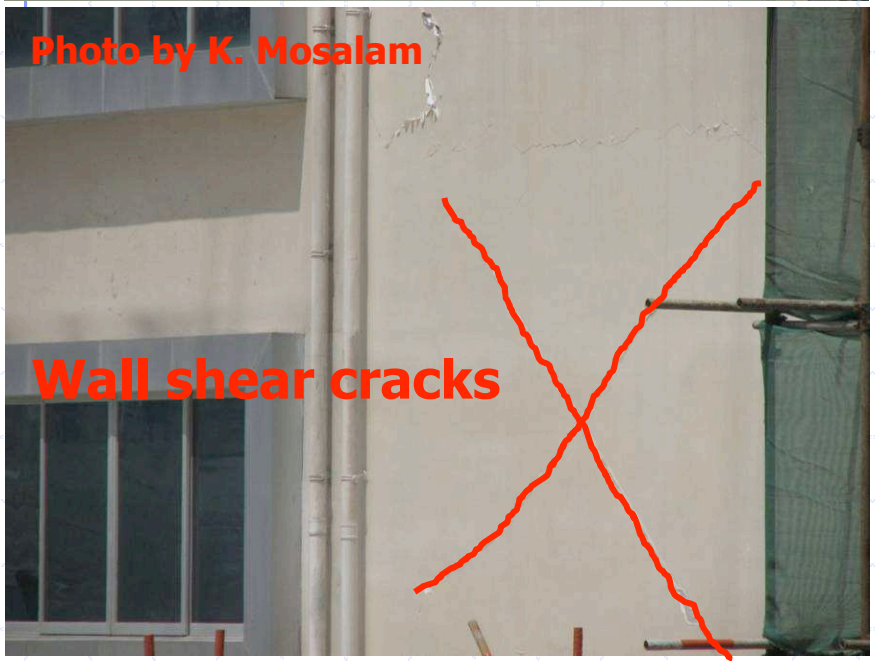
Zipingpu Dam (6/7)





Zipingpu Dam (7/7)



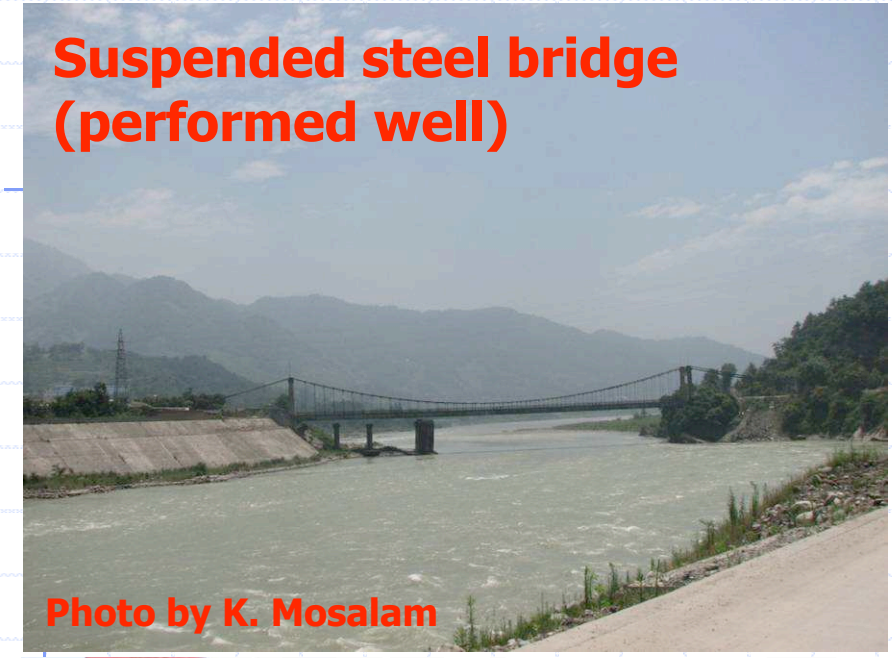


Yingxiu & Xuankou Towns

Outline

- Bridges
- Middle school

Bridges (1/4)


Suspended steel bridge
(performed well)
Photo by K. Mosalam

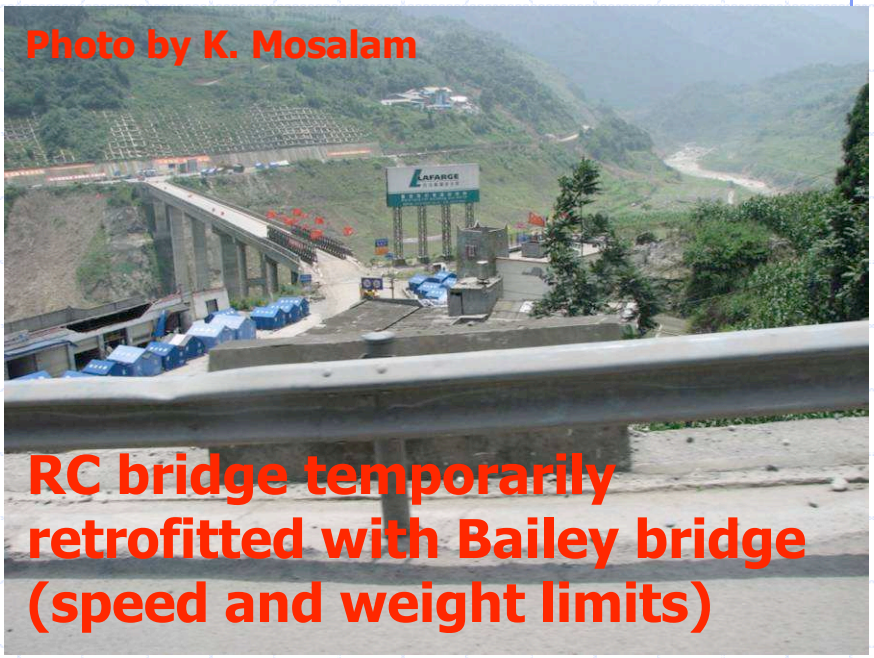


Photo by K. Mosalam
RC bridge temporarily
retrofitted with Bailey bridge
(speed and weight limits)


20t
Photo by K. Mosalam


Photo by K. Mosalam

Bridges (2/4)


Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam

Bridges (3/4)


Photo by K. Mosalam

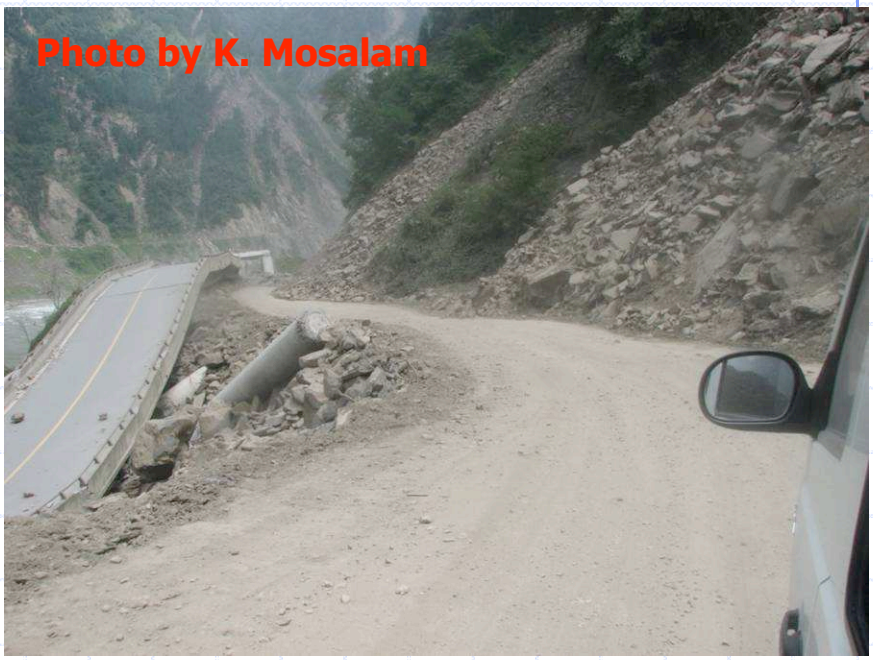


Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam

Bridges (4/4)


Collapsed intermediate span of a multi-span bridge over Zipingpu reservoir
Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam

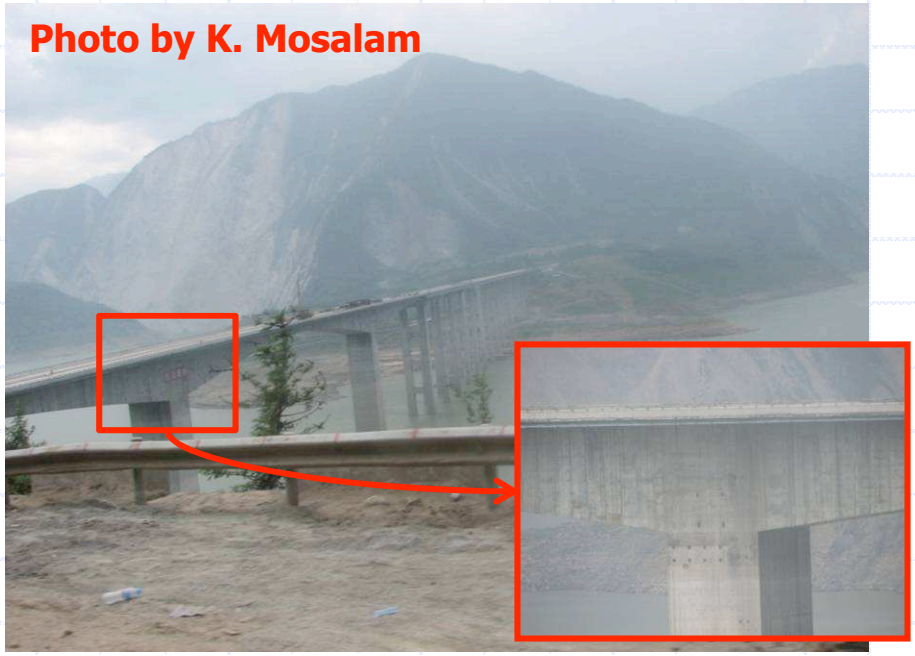


Photo by K. Mosalam

Middle School

Hongkou Town

Outline

- Fault trace
- Steel building
- Buildings under construction and RC slabs
- RC Columns
- RC Beam-column joints
- Overall frame failure
- Hongkou bridge – faulting induced collapse
- Traditional versus modern structures

Fault Trace

Photos by K. Mosalam

SE side up > 2m

Crane 1

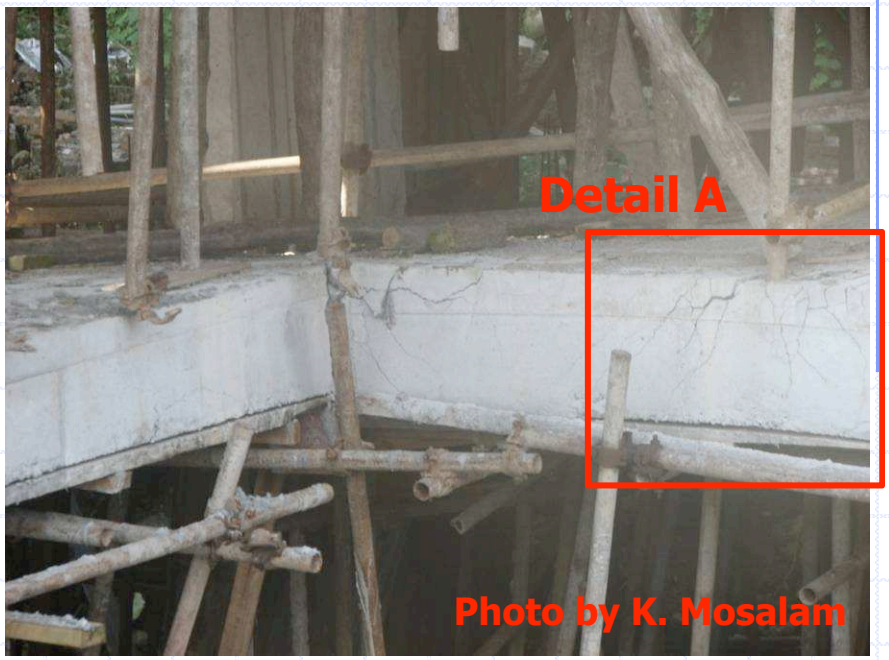
Crane 2

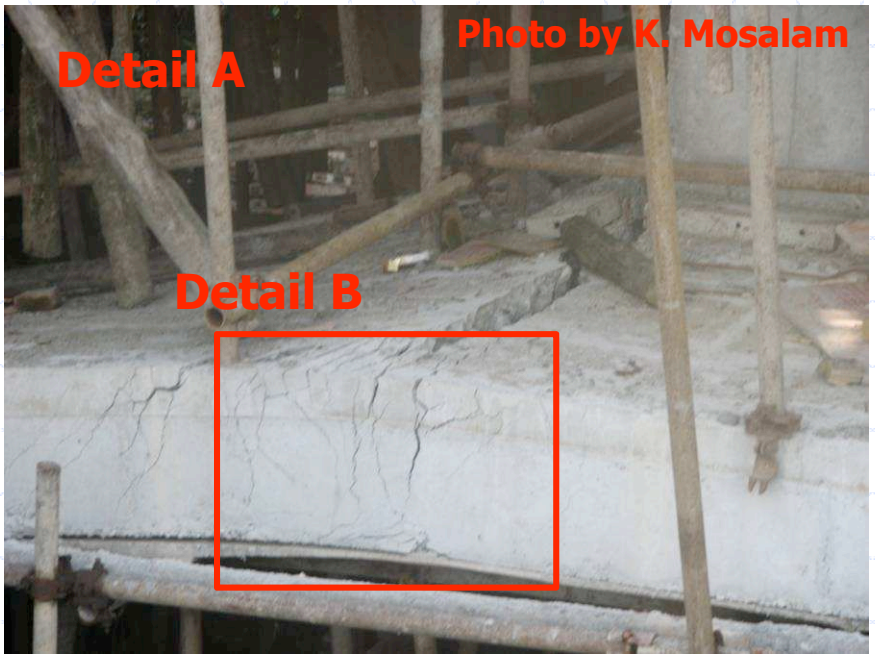
Crane 3 (Collapsed)

Steel Building

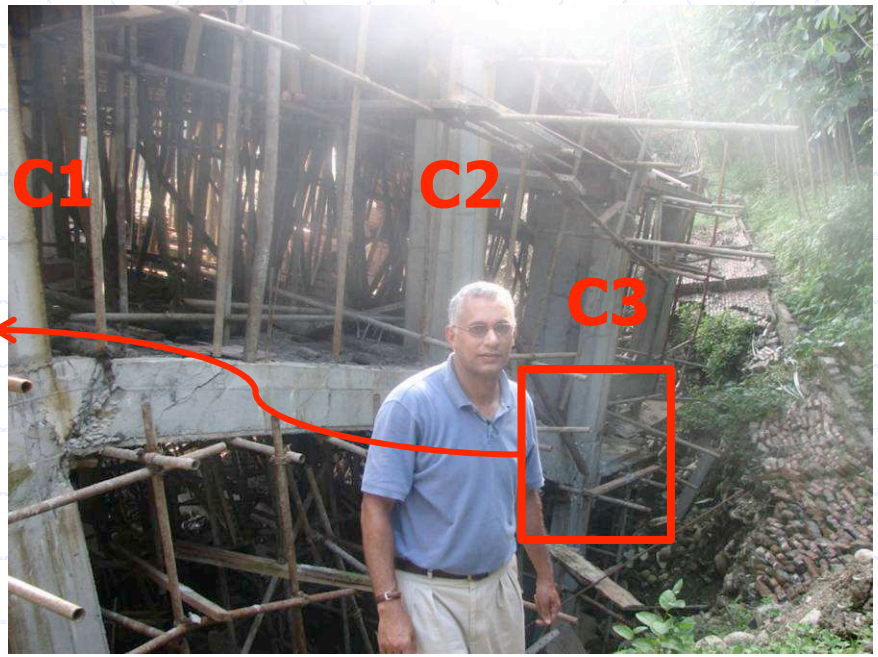
Good performance – within the fault zone

Buildings under Construction and RC Slabs (1/2)





Buildings under Construction and RC Slabs (2/2)



RC Columns


C1
C2
Photo by K. Mosalam

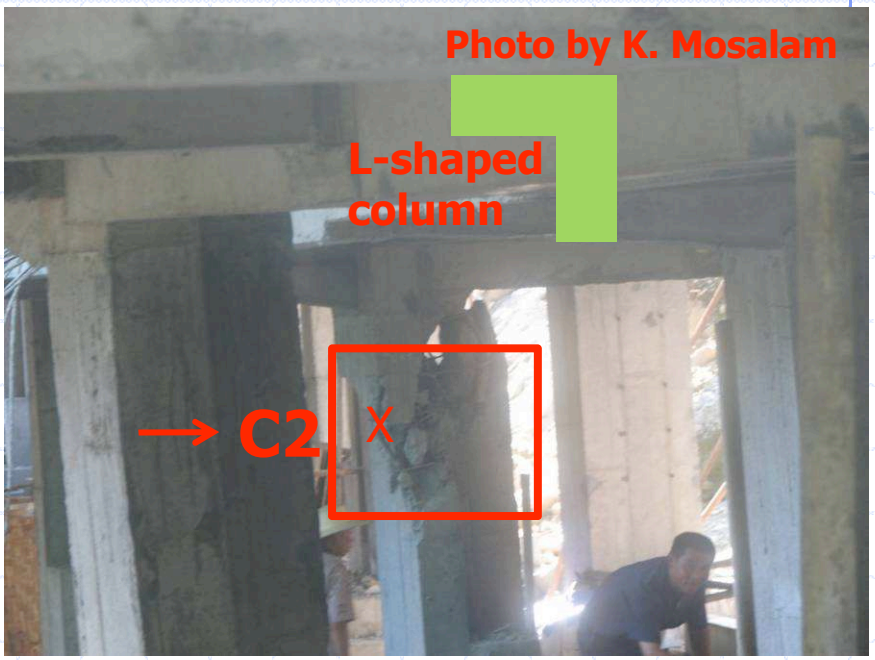
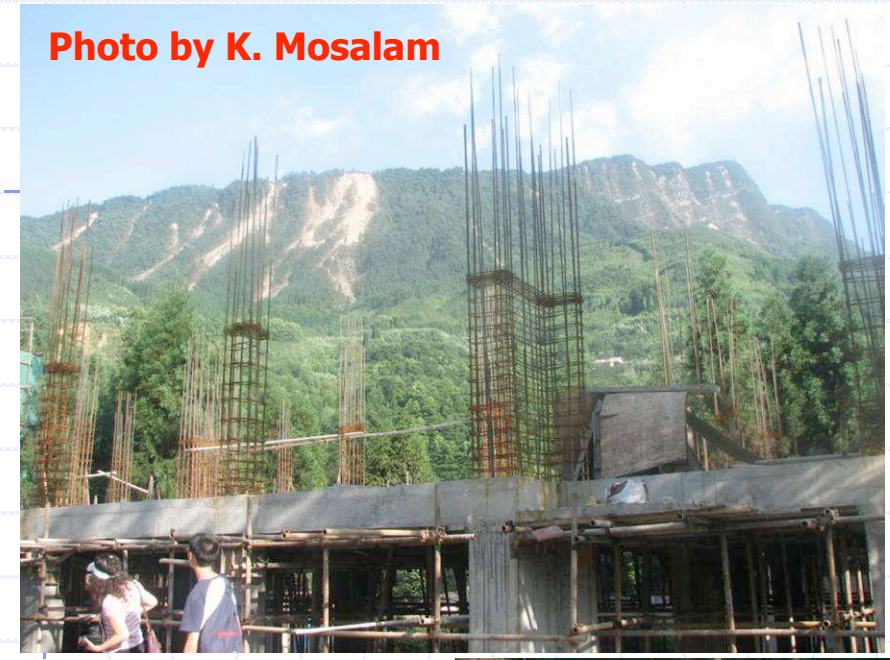


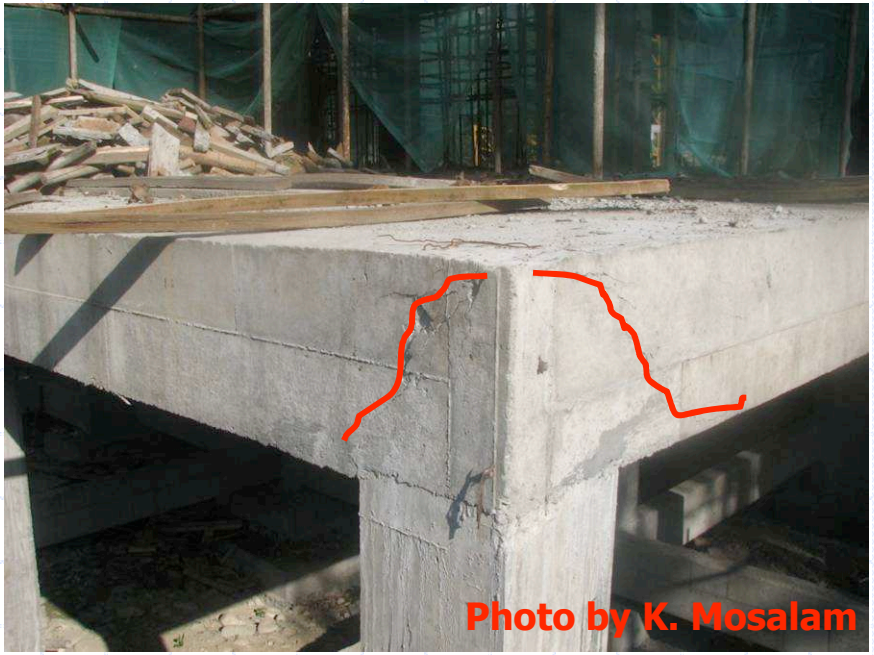
Photo by K. Mosalam
L-shaped column
C2
X


Photo by K. Mosalam
C1

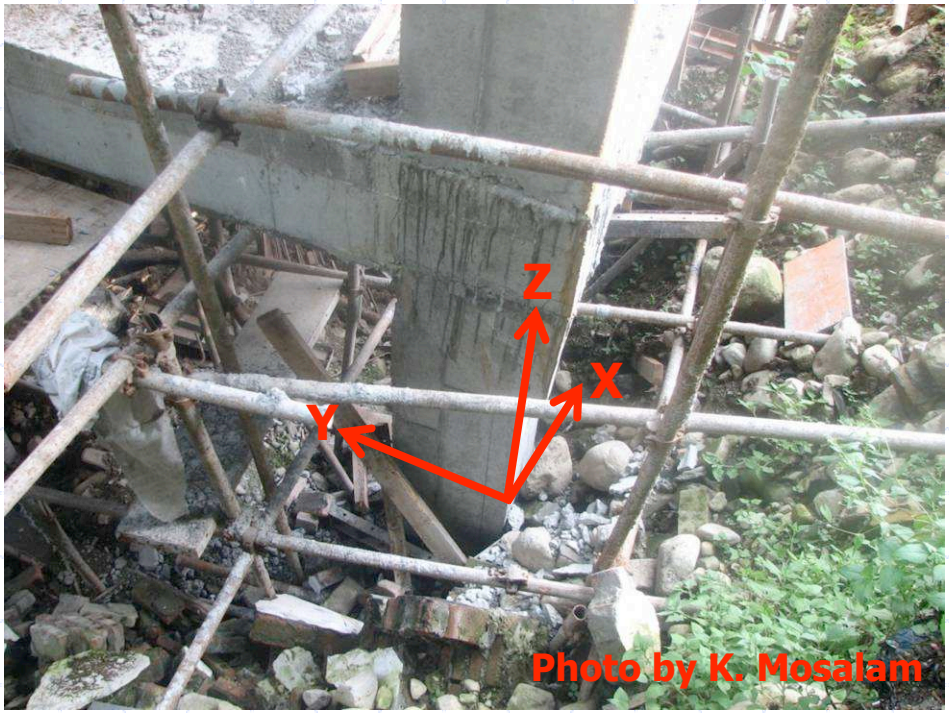

C2
X
Photo by K. Mosalam

RC Beam-Column Joints (1/2)





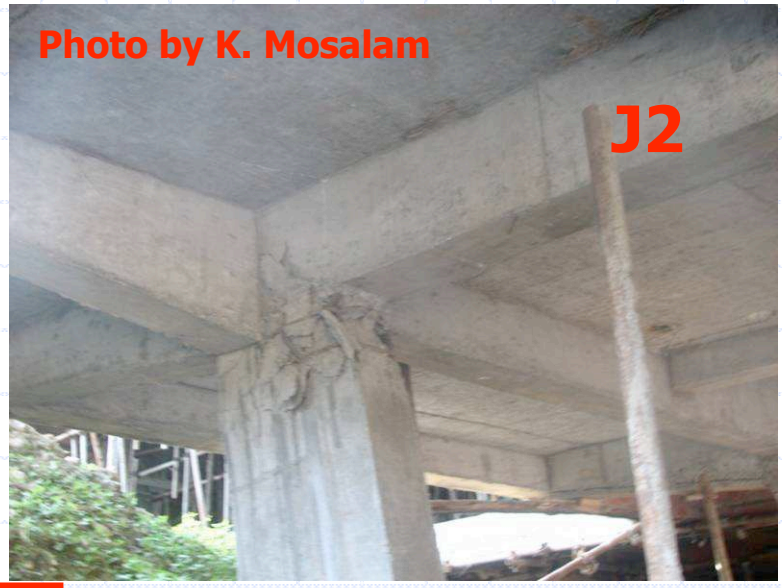
RC Beam-Column Joints (2/2)



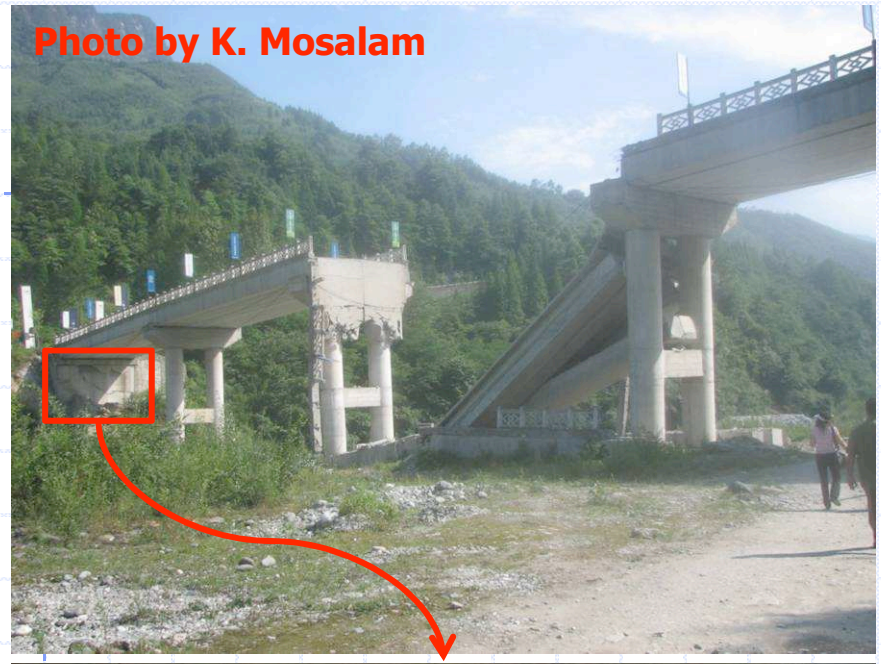
RC Frame Failure Due to Faulting (1/2)

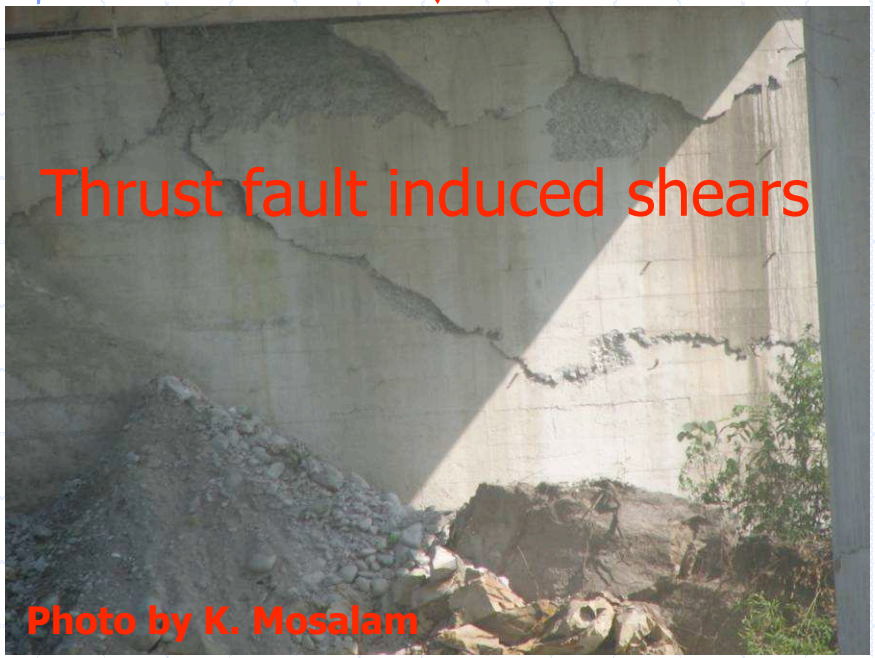
Photo by K. Mosalam

RC Frame Failure Due to Faulting (2/2)

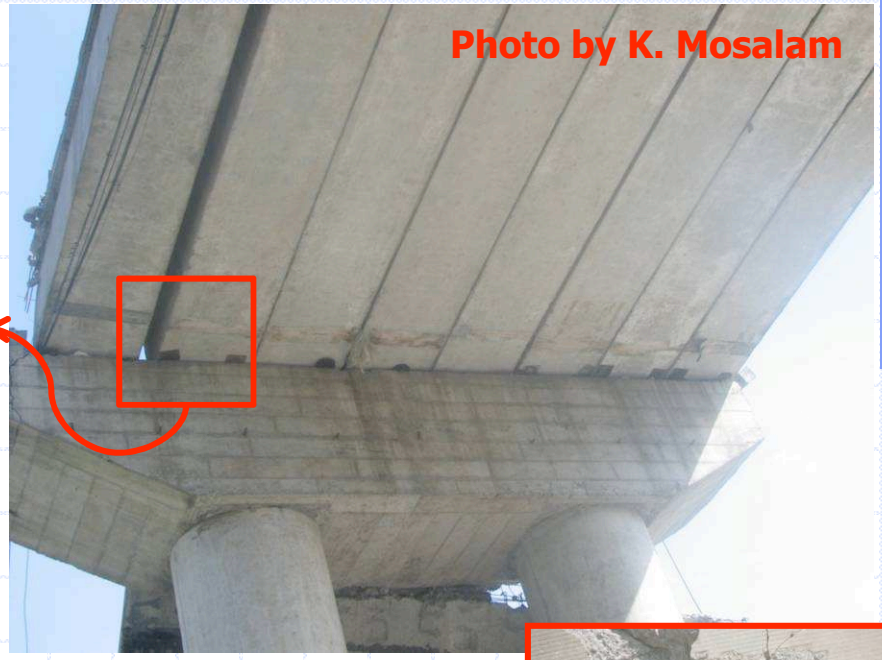


Hongkou Bridge – Faulting Induced Collapse (1/3)

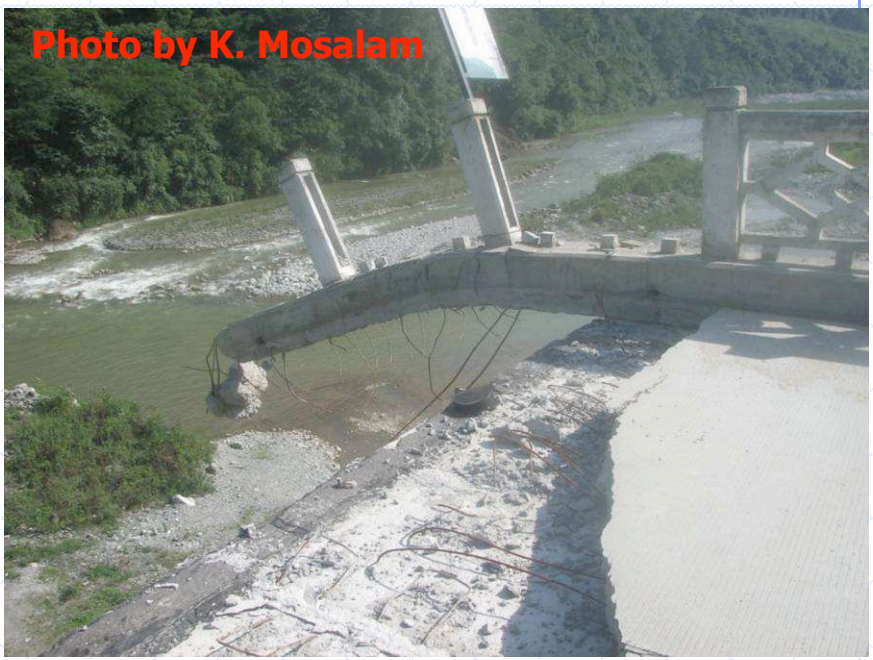




Hongkou Bridge – Faulting Induced Collapse (2/3)



Hongkou Bridge – Faulting Induced Collapse (3/3)



Traditional versus Modern Structures (1/2)

Photo by K. Mosalam

Photo by K. Mosalam

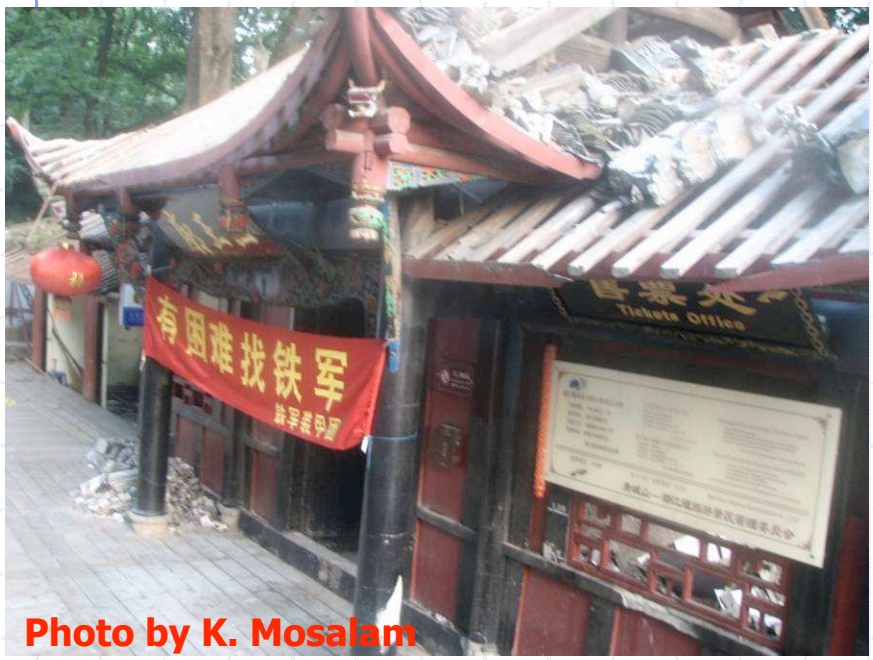


Photo by K. Mosalam

Photo by K. Mosalam

Traditional versus Modern Structures (2/2)

Hanwang Town (Mianzhu City)

Outline

- Good performance
- Fair performance
- Poor performance (Complete/Partial collapses)
- Bridge collapse and fault trace
- Infill walls/Masonry
- RC Beam-column joints

Clock stopped working

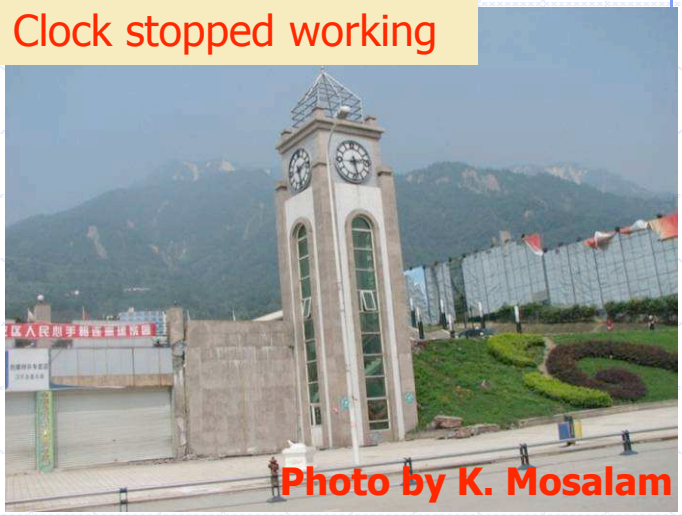


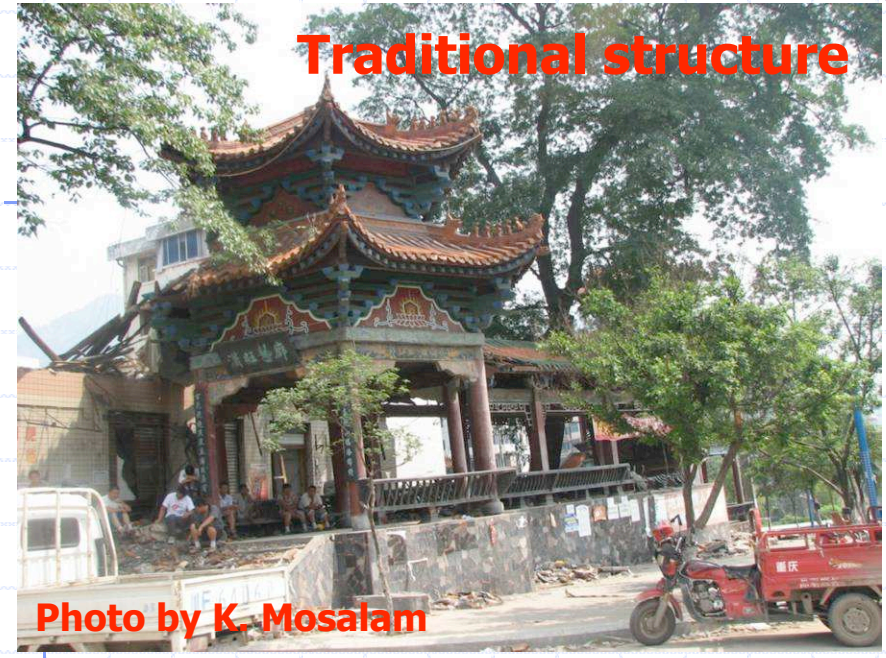
Photo by K. Mosalam

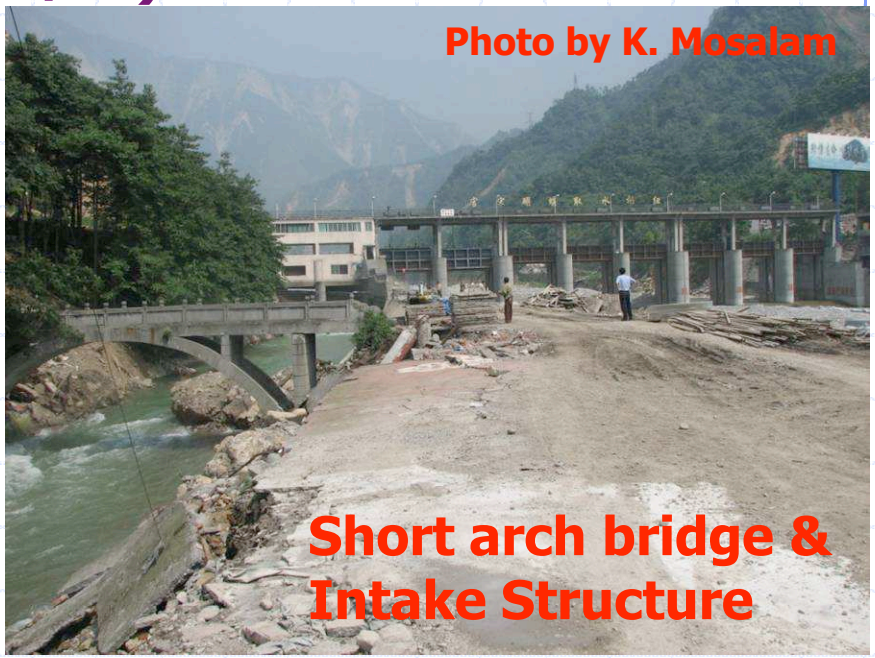
Time of earthquake

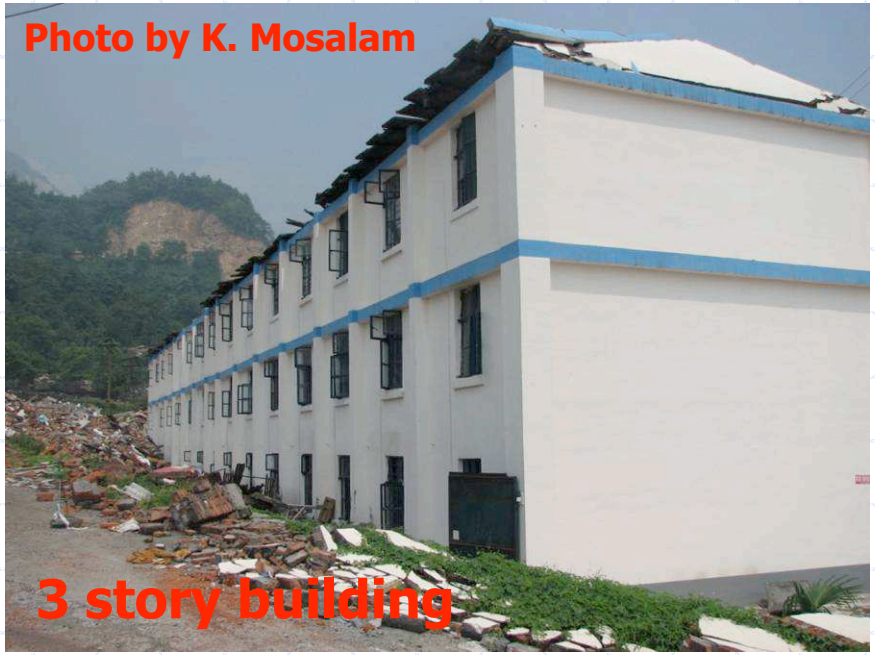
Photo by K. Mosalam

Good Performance (1/2)

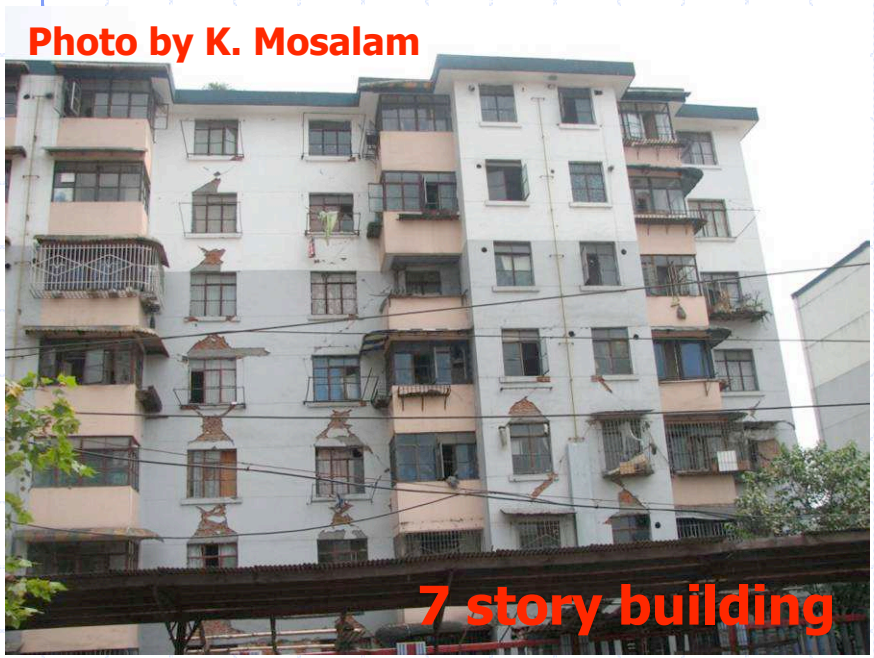
Good Performance (2/2)





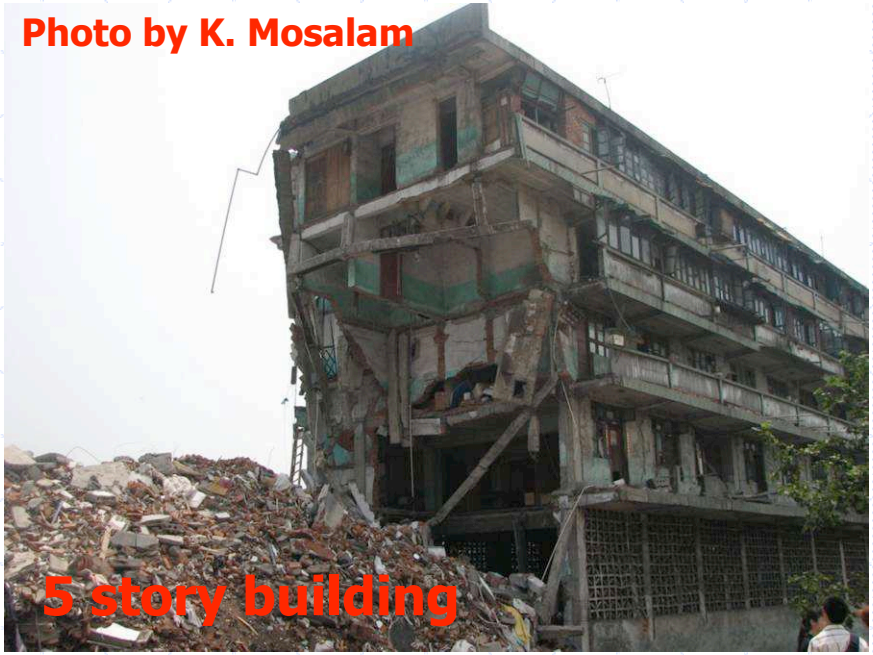


Fair Performance



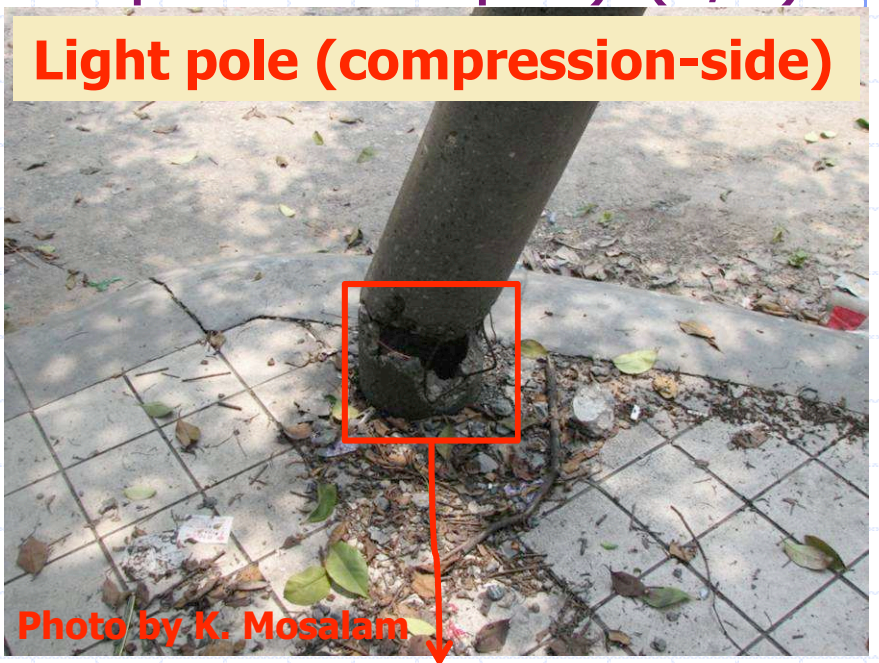
Poor Performance (Partial/Complete Collapse) (1/5)

Poor Performance (Partial/Complete Collapse) (2/5)



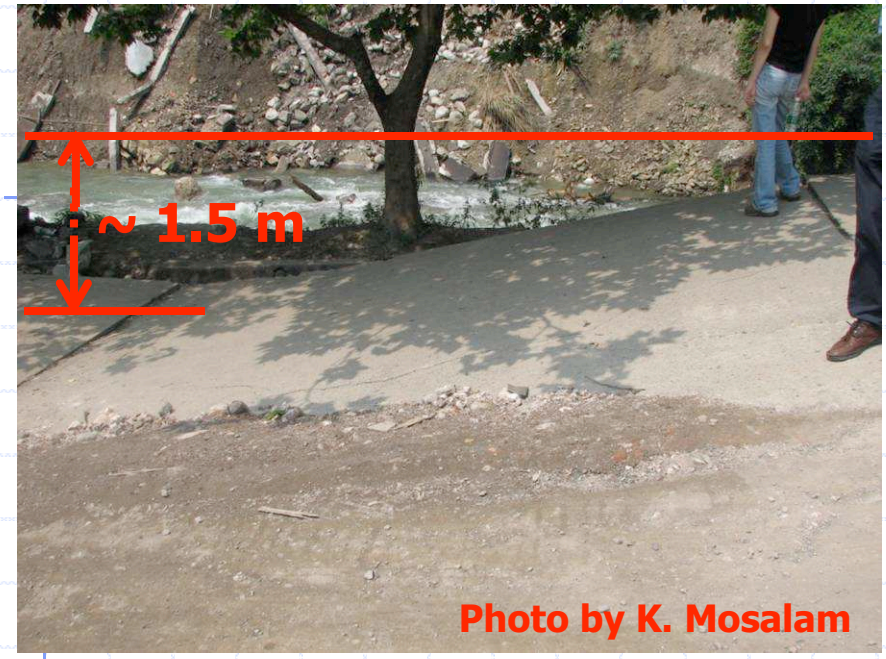
Poor Performance (Partial/Complete Collapse) (3/5)

Poor Performance (Partial/Complete Collapse) (4/5)



Poor Performance (Partial/Complete Collapse) (5/5)

Bridge Collapse and Fault Trace



Infill Walls (Poor Performance)

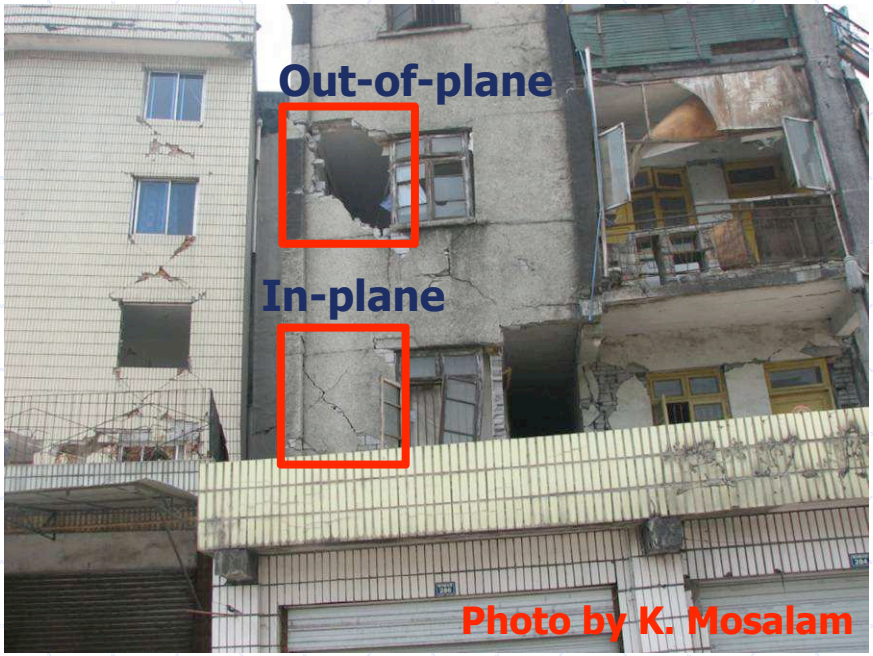
Photo by K. Mosalam

Photo by K. Mosalam


Photo by K. Mosalam

Infill Walls (Good Performance)

Masonry (Poor Performance)



Masonry (Good Performance)

2 story confined masonry residential buildings built in 2006 performed well (Gao Yuan Village)

RC Beam-Column Joints (1/2)

Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam


Photo by K. Mosalam

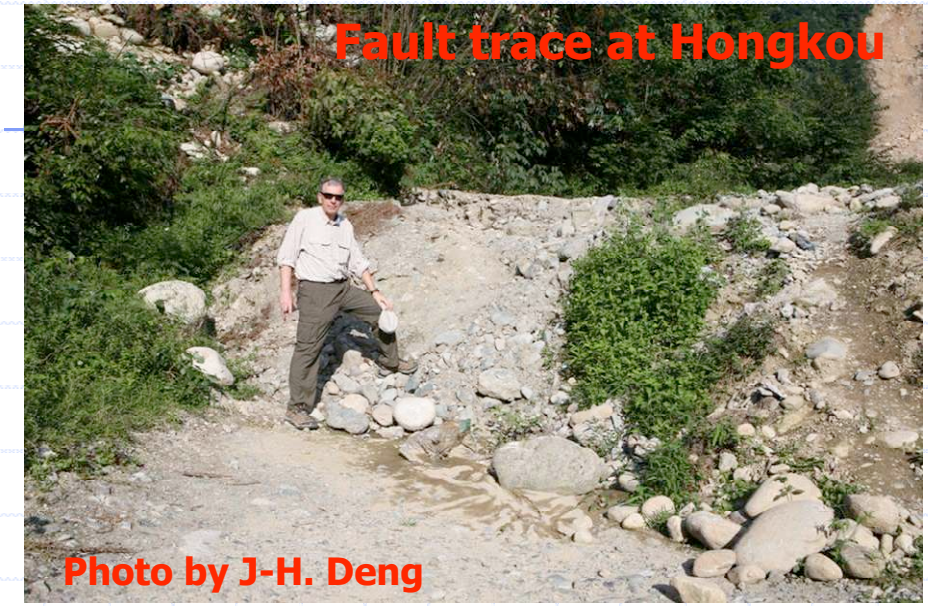
RC Beam-Column Joints (2/2)

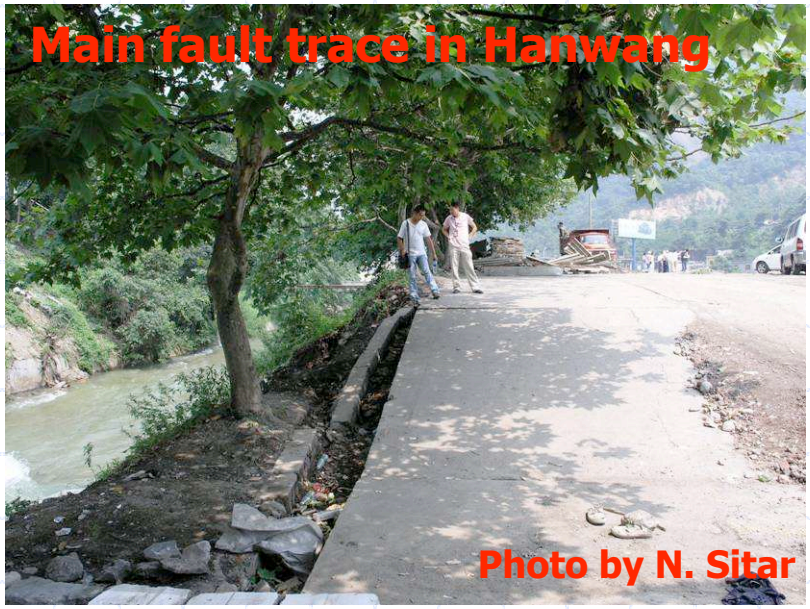
Faulting and Landslides

Outline

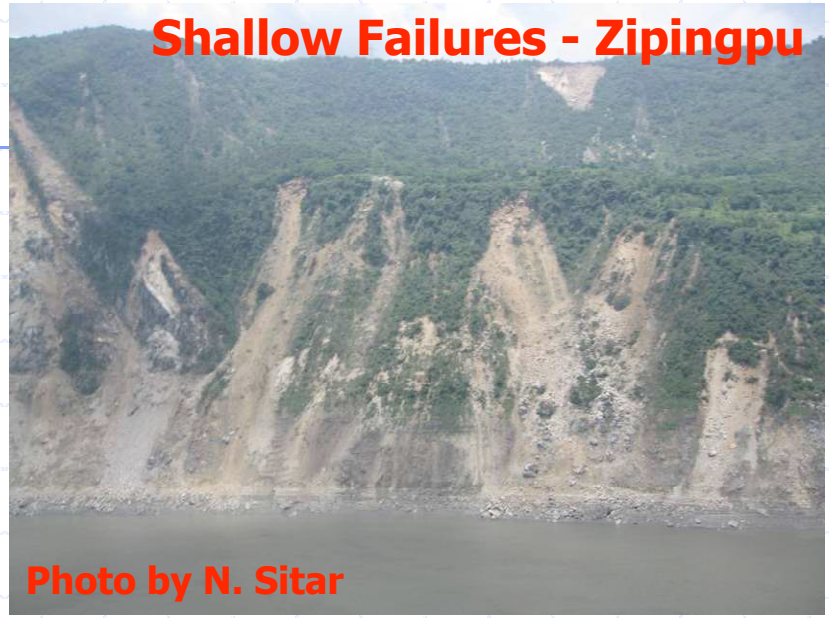
- Fault features - steeply dipping reverse faults
- Rock falls and landslides
- Slope stabilization – excellent performance

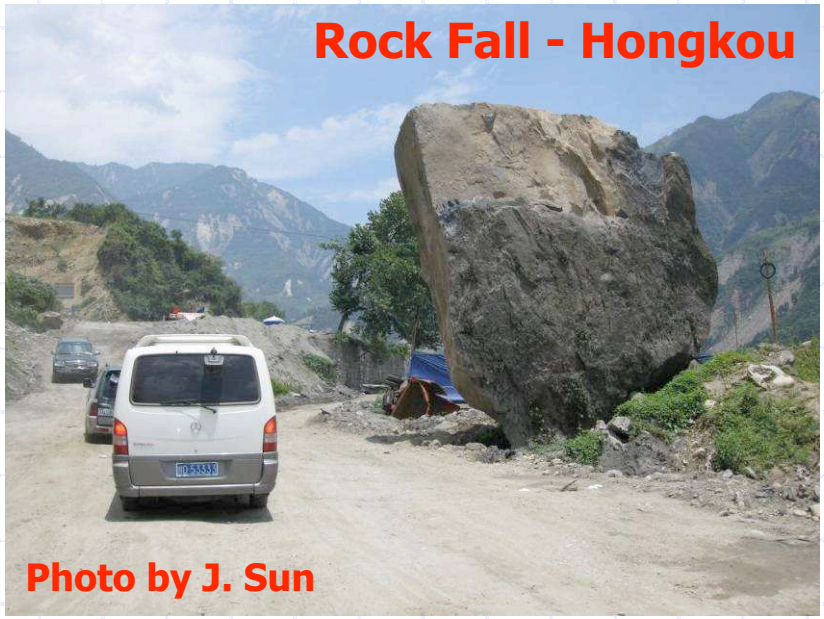
Fault Features – Steeply Dipping Reverse Faults





Rock Falls and Landslides





Slope Stabilization – Excellent Performance

Rock Bolts and Shotcrete – Zipingpu

Photo by N. Sitar

Zipingpu Dam – Right Abutment

Photo by N. Sitar

Road to Yingxiu

Photo by J. Sun

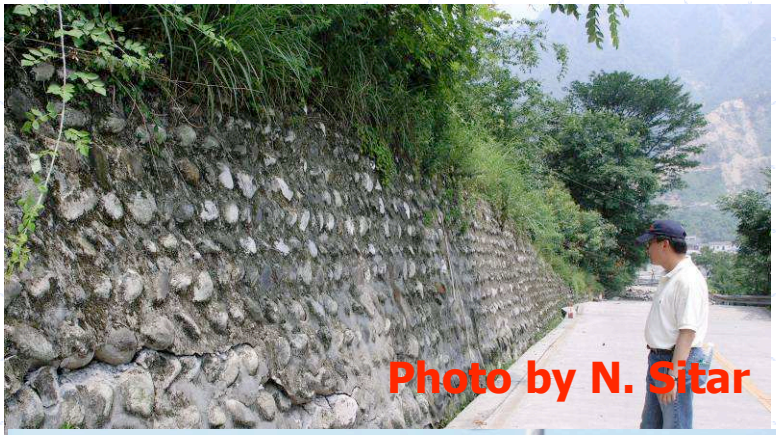
Tunnels and Retaining Structures

Outline

- Tunnels – minor damage along bedding plane shears
- Conventional retaining structures – minimal or no damage

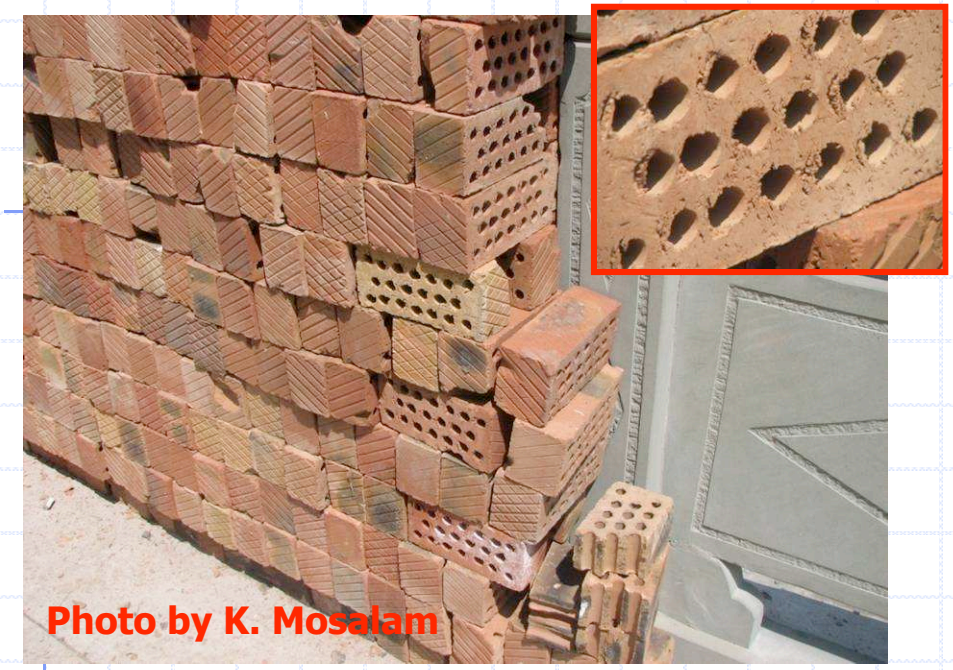
Tunnels – Minor Damage along Bedding Plane Shears

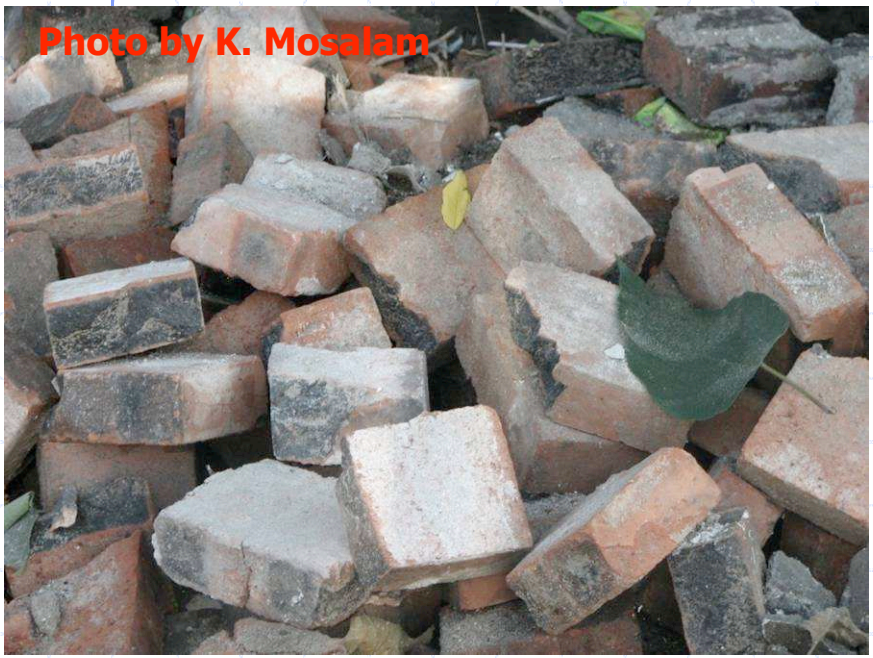
Conventional Retaining Structures – Minimal or No Damage



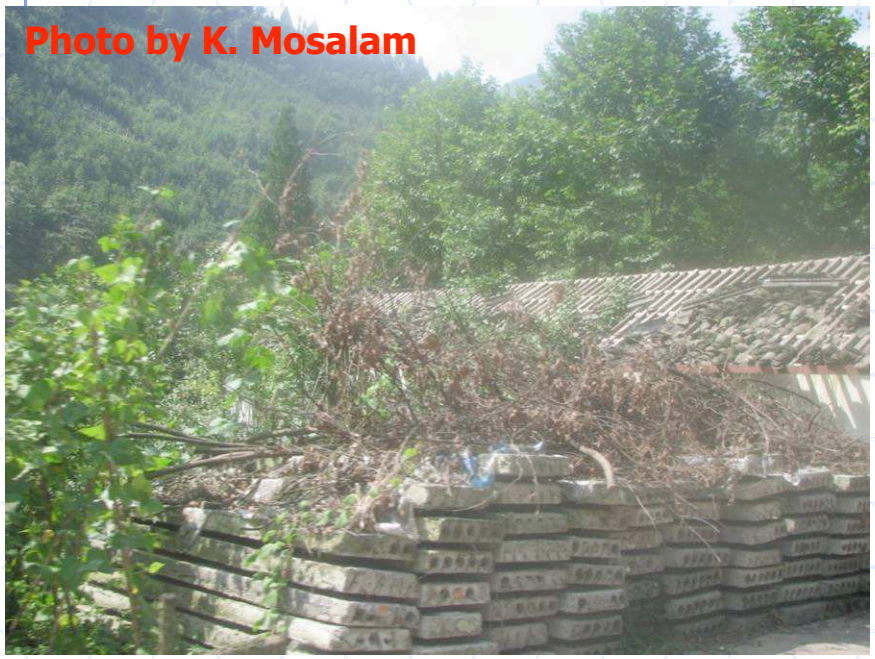
Materials and Reconstruction

Materials and Reconstruction (1/4)





Materials and Reconstruction (2/4)



Materials and Reconstruction (3/4)

Materials and Reconstruction (4/4)

Concluding Remarks

1. Material quality (reinforced concrete, masonry)
2. Deformation compatibility (stair-wells)
3. Mixed role of unreinforced masonry infill walls
4. Poor diaphragm action (concrete planks)
5. Beam-column joints
6. Better performance of tall structures
7. Poor performance of short structures
8. Mixed response of mid-rise structures
9. Poor performance of bridges with limited or no redundancy
10. Multiple reverse fault traces along the principal fault lines
11. Thousands of slope failures and rock falls
12. Excellent performance of slope stabilization measures, tunnels and retaining walls.

Thank You!