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Beijing, China
Aug. 11~12, 2014

Scenario Simulation and Engineering Solution for Extreme Disasters

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Introductions

Extreme disasters

not considered in conventional design

Very low occurrence possibility

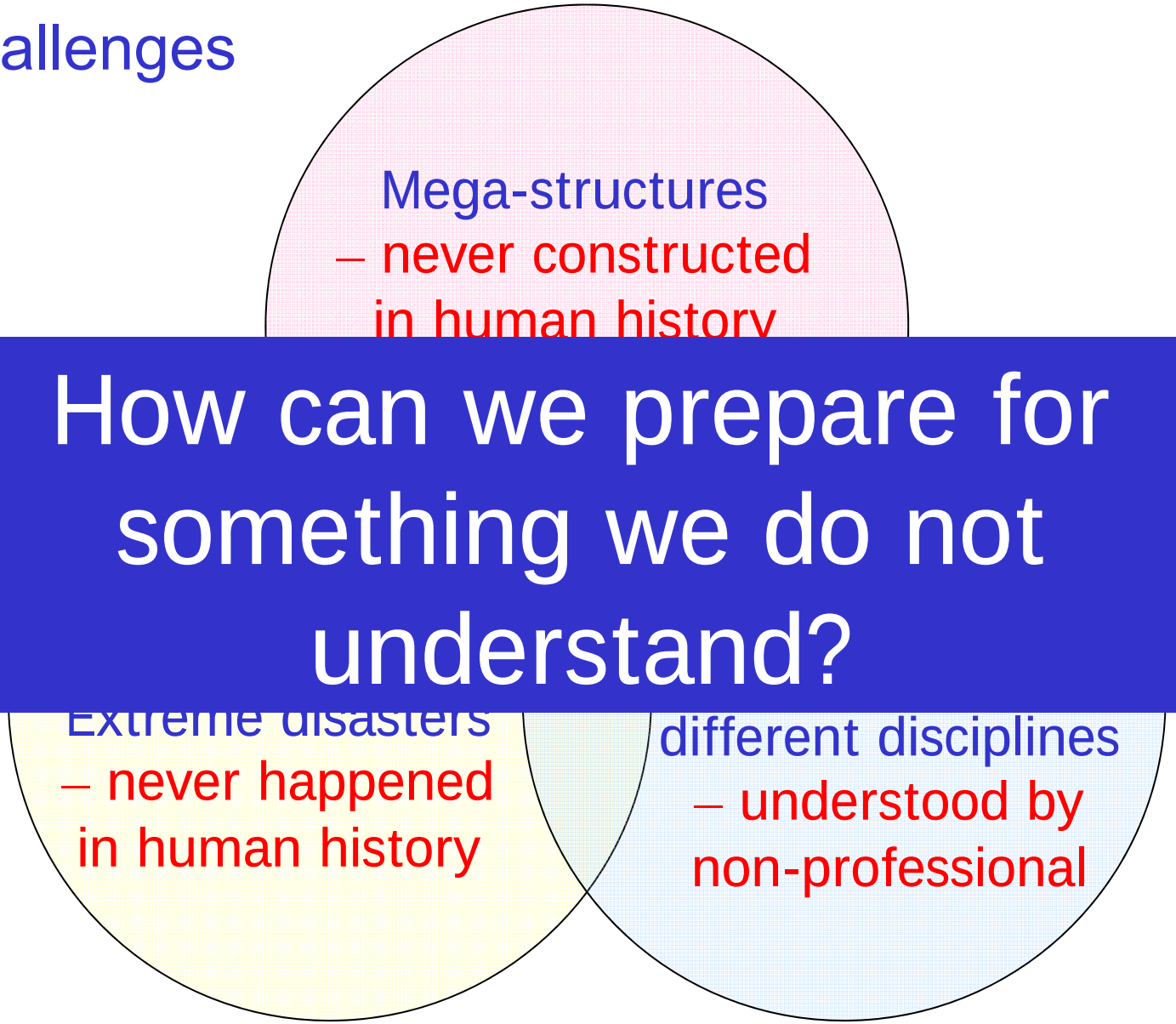
Lack of knowledge

Very severe consequences

Must be prepared for

Introductions

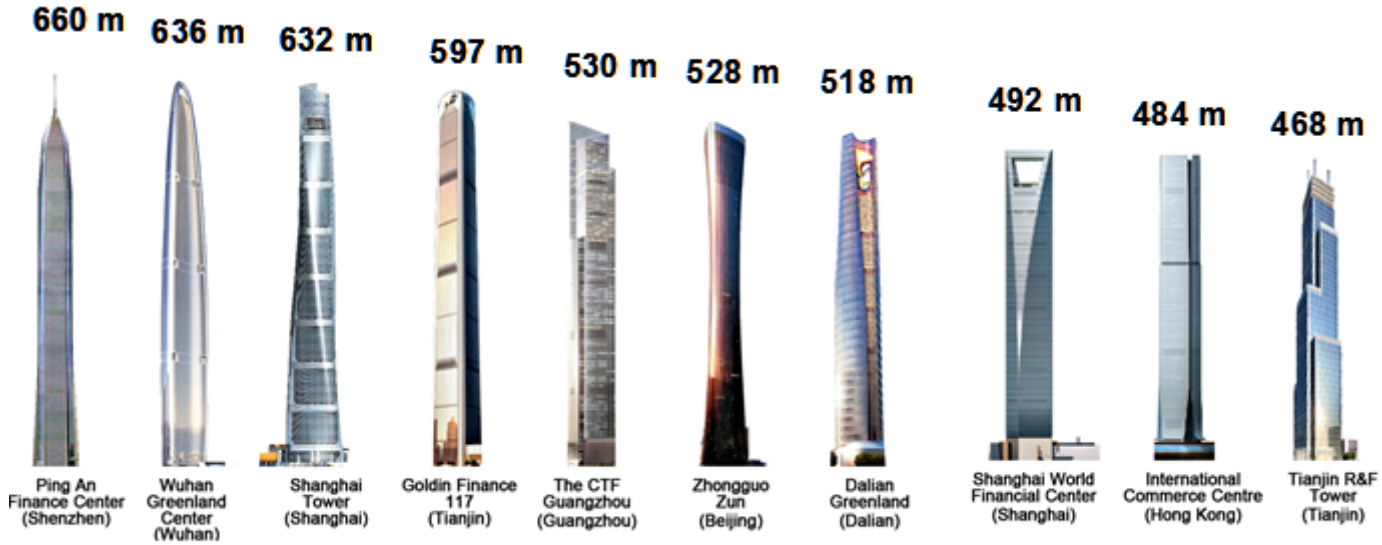
- Challenges

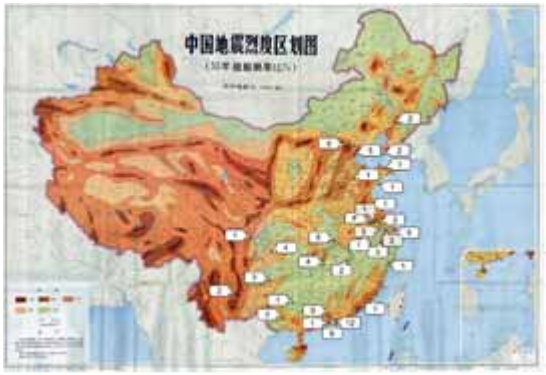


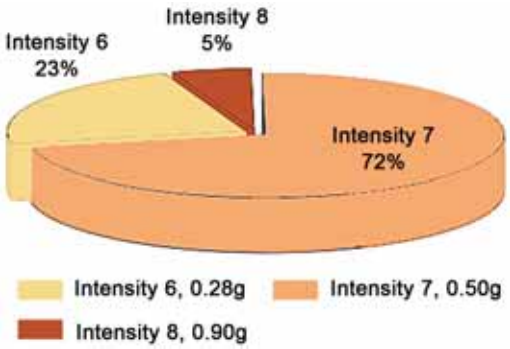
How can we prepare for something we do not understand?

Introductions

- Typical super-tall buildings in China



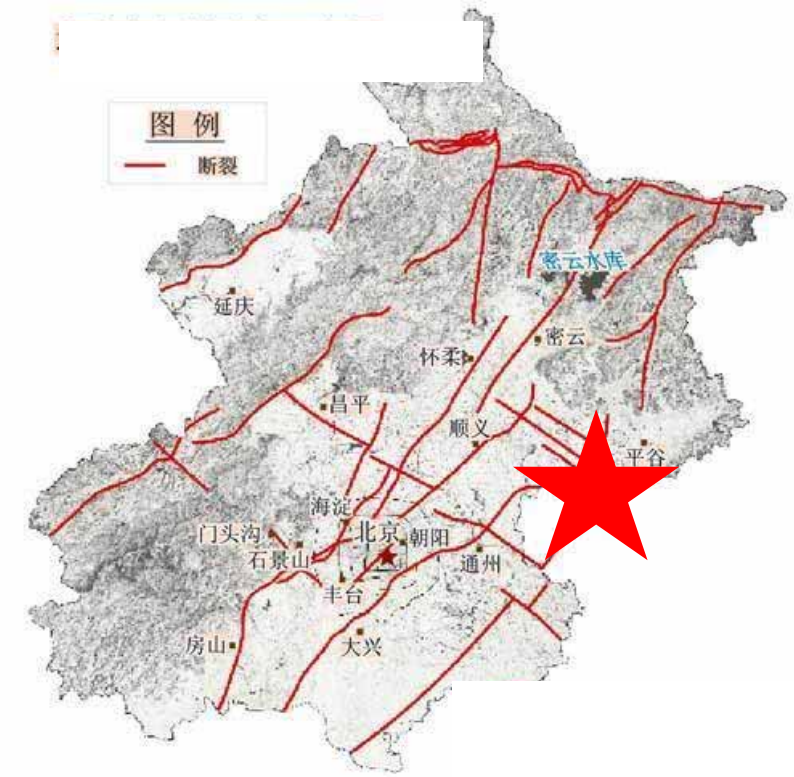




Distribution of super-tall buildings (>300m) in China

Introductions

- Extreme disasters



1679, M8.0 Earthquake in Beijing

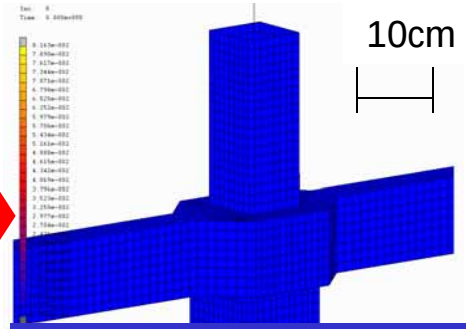
Introductions

Scenario simulation

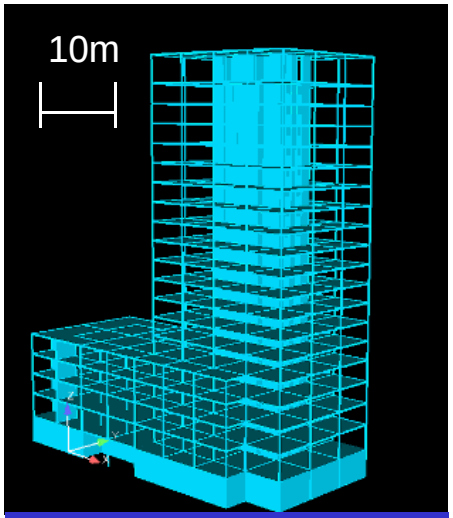
From Micro-scale
to Macro-scale

Engineering solution

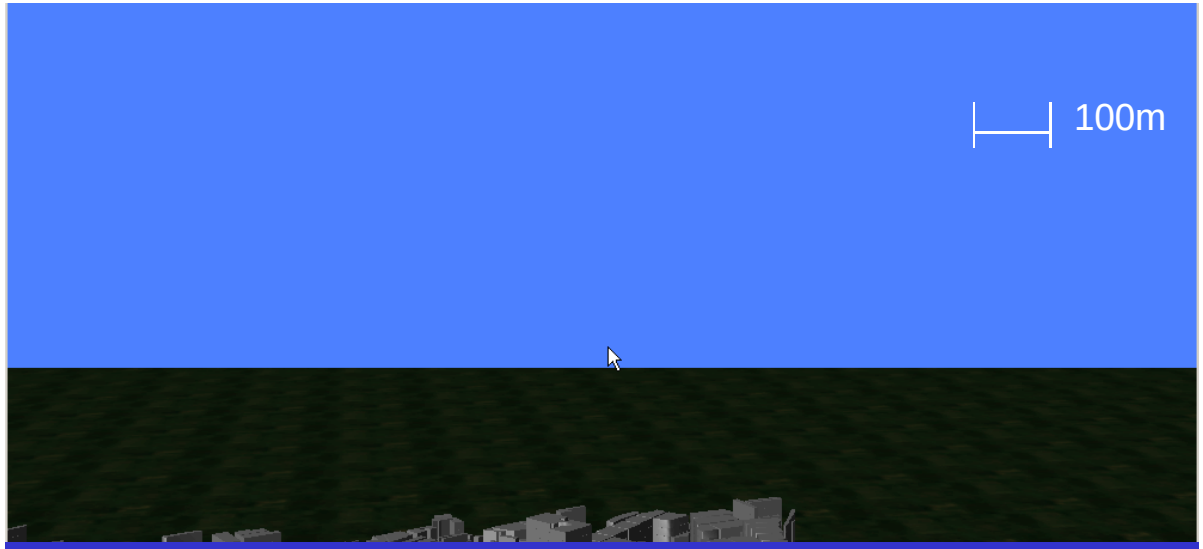
Material scale



Component scale



Structural scale



City/regional scale

Typical examples

Super-tall buildings

Scenario simulation

Engineering solution

Large-span bridges

High-speed railway station

Nuclear power plant

Numerical model

Experimental validation

Engineering solution

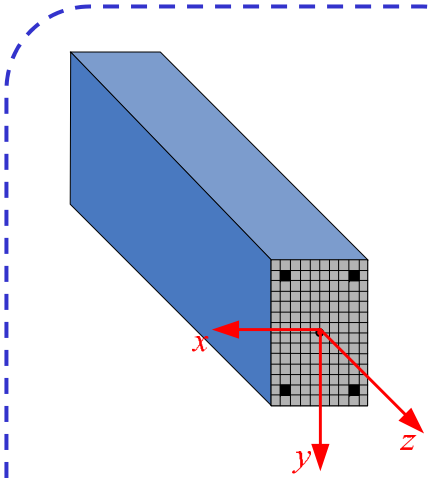
Design of the tallest building in Beijing

Z15 (Chinese Cup)

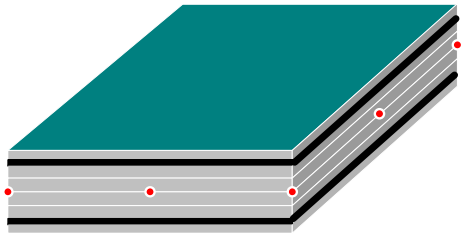
- Height > 500m
- Seismic intensity 8
- Tallest building in such intensity

Design of the tallest building in Beijing

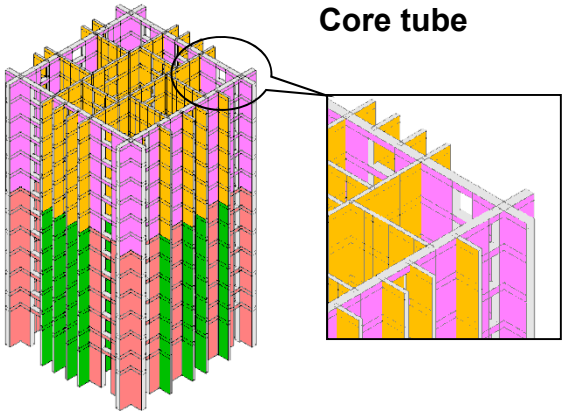
- Numerical model

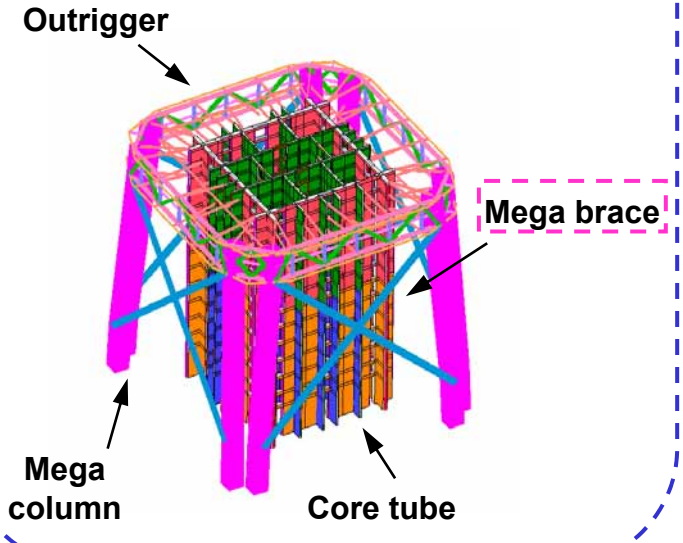


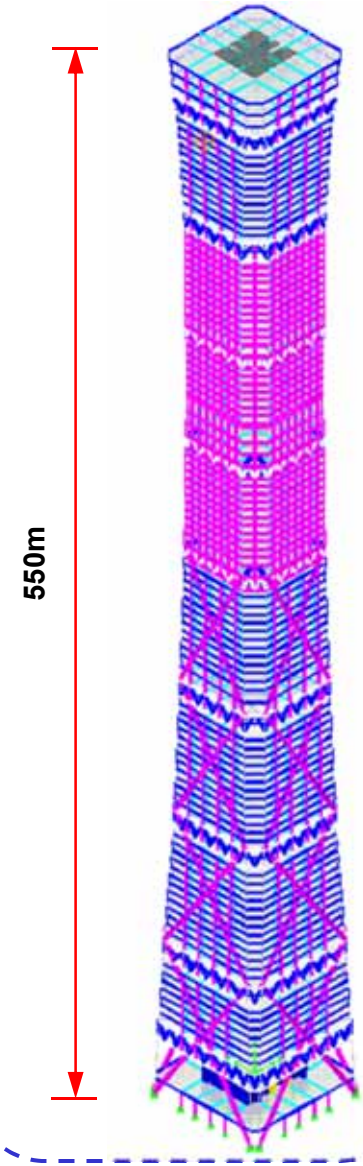
Fiber beam element model



Multi-layer shell element model

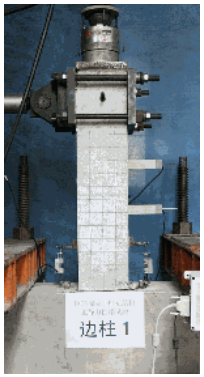


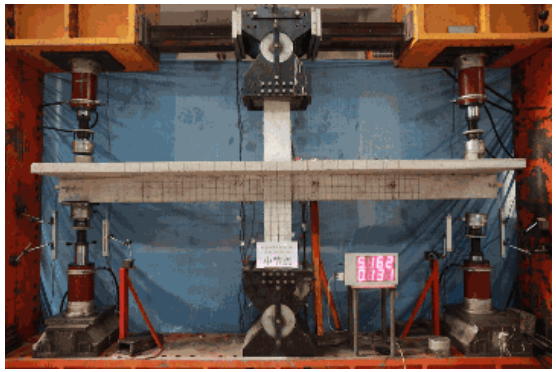


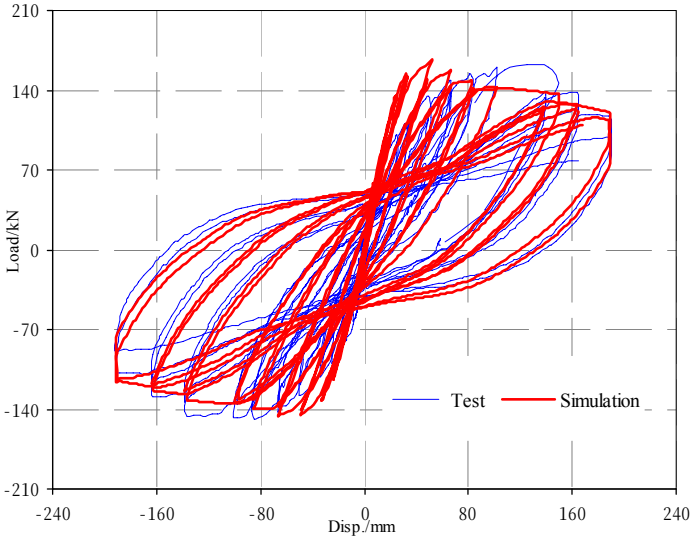


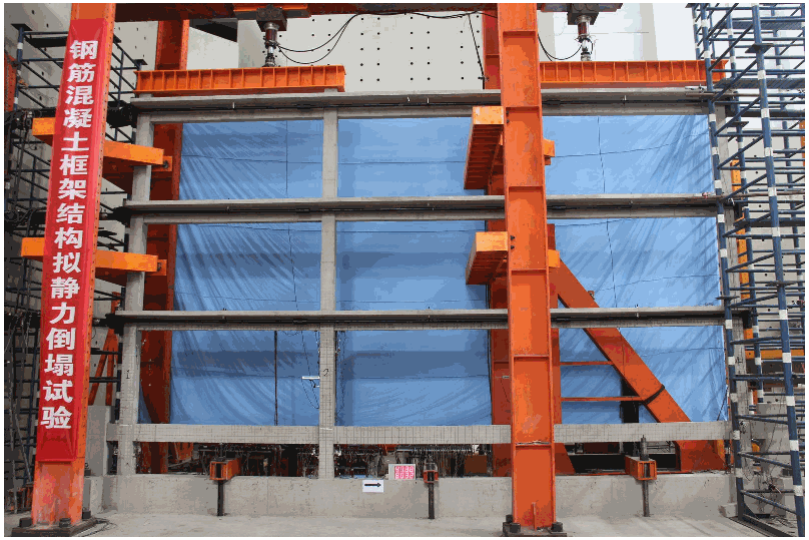
Design of the tallest building in Beijing

- Experimental validation





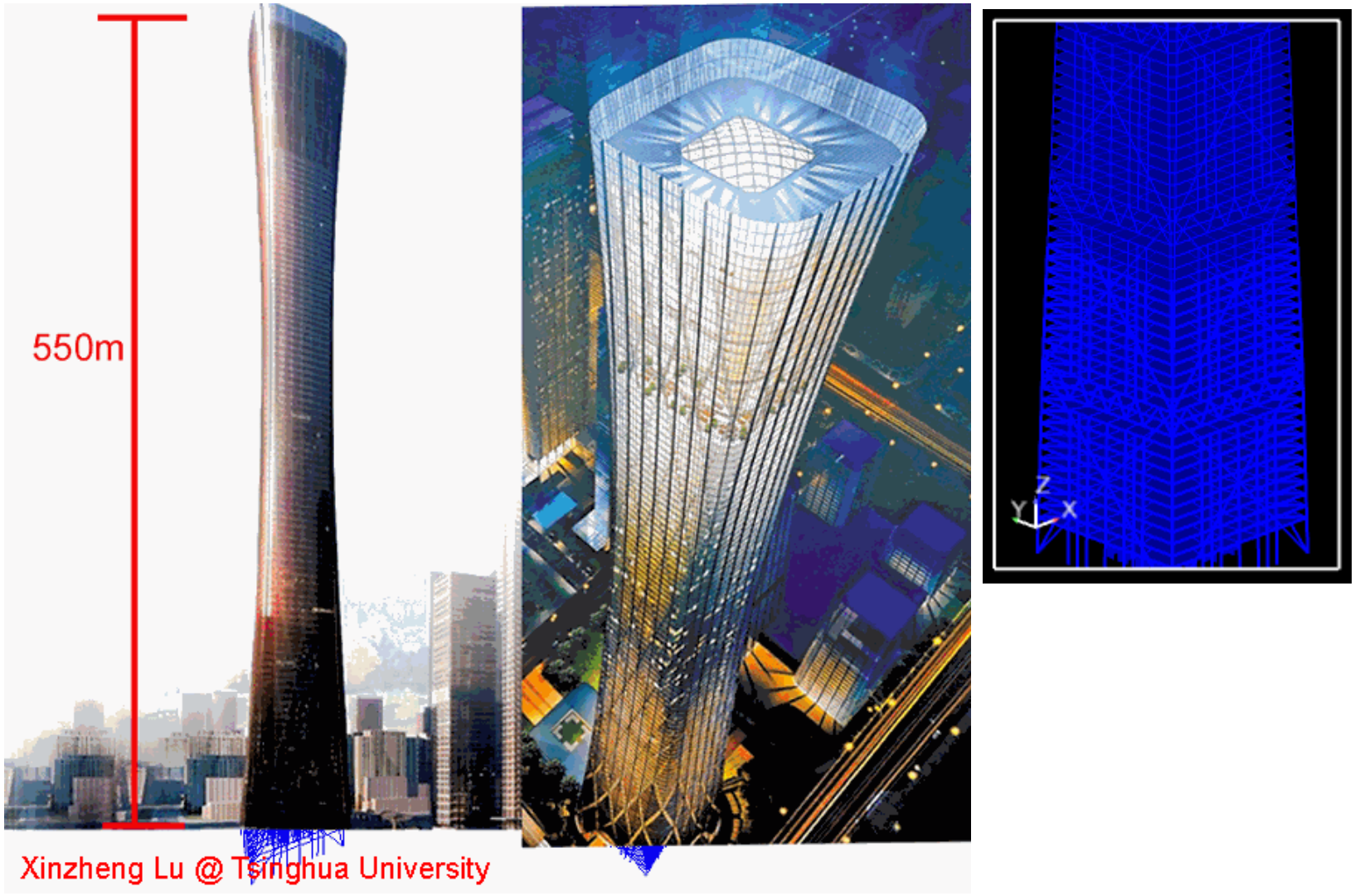




Lu X, Lu XZ, et al., Collapse simulation of reinforced concrete high-rise building induced by extreme earthquakes, *Earthquake Engineering & Structural Dynamics*, 2013

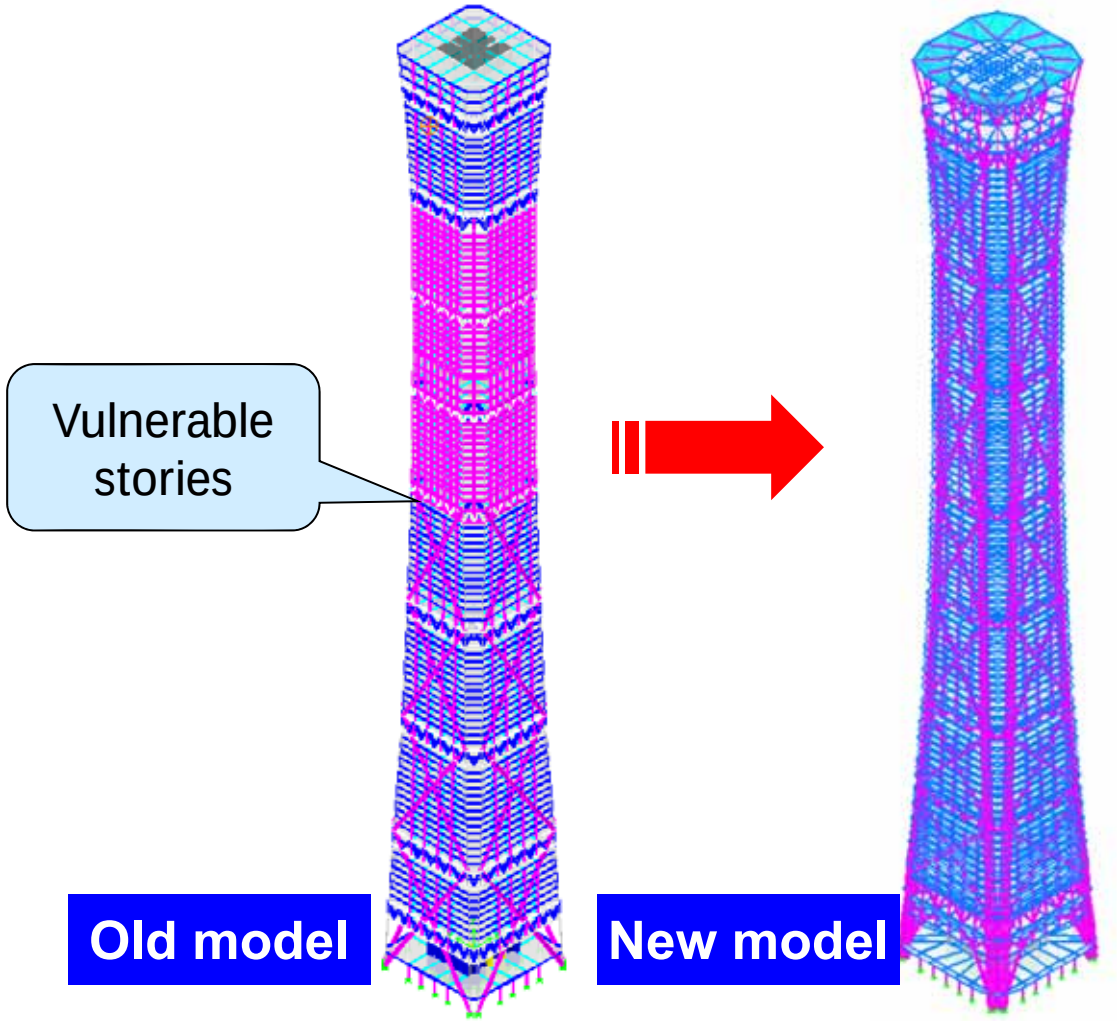
Design of the tallest building in Beijing

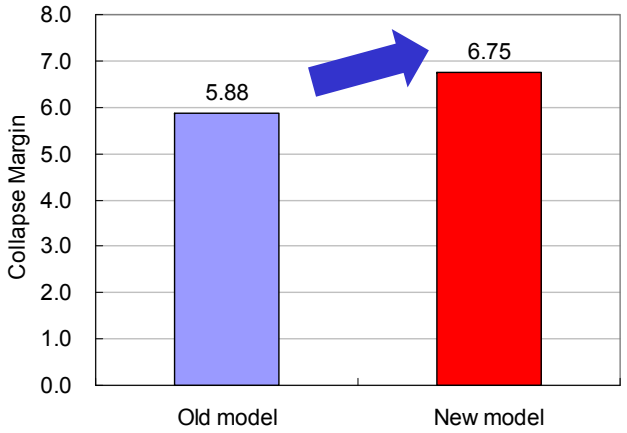
- Scenario simulation



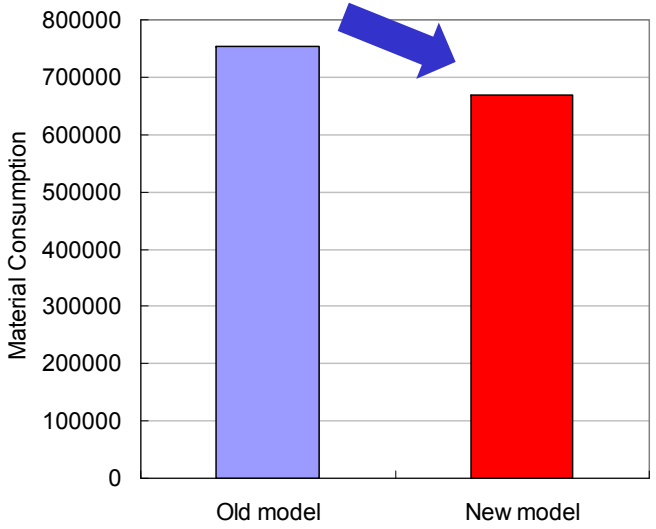
Design of the tallest building in Beijing

- Proposed engineering solution

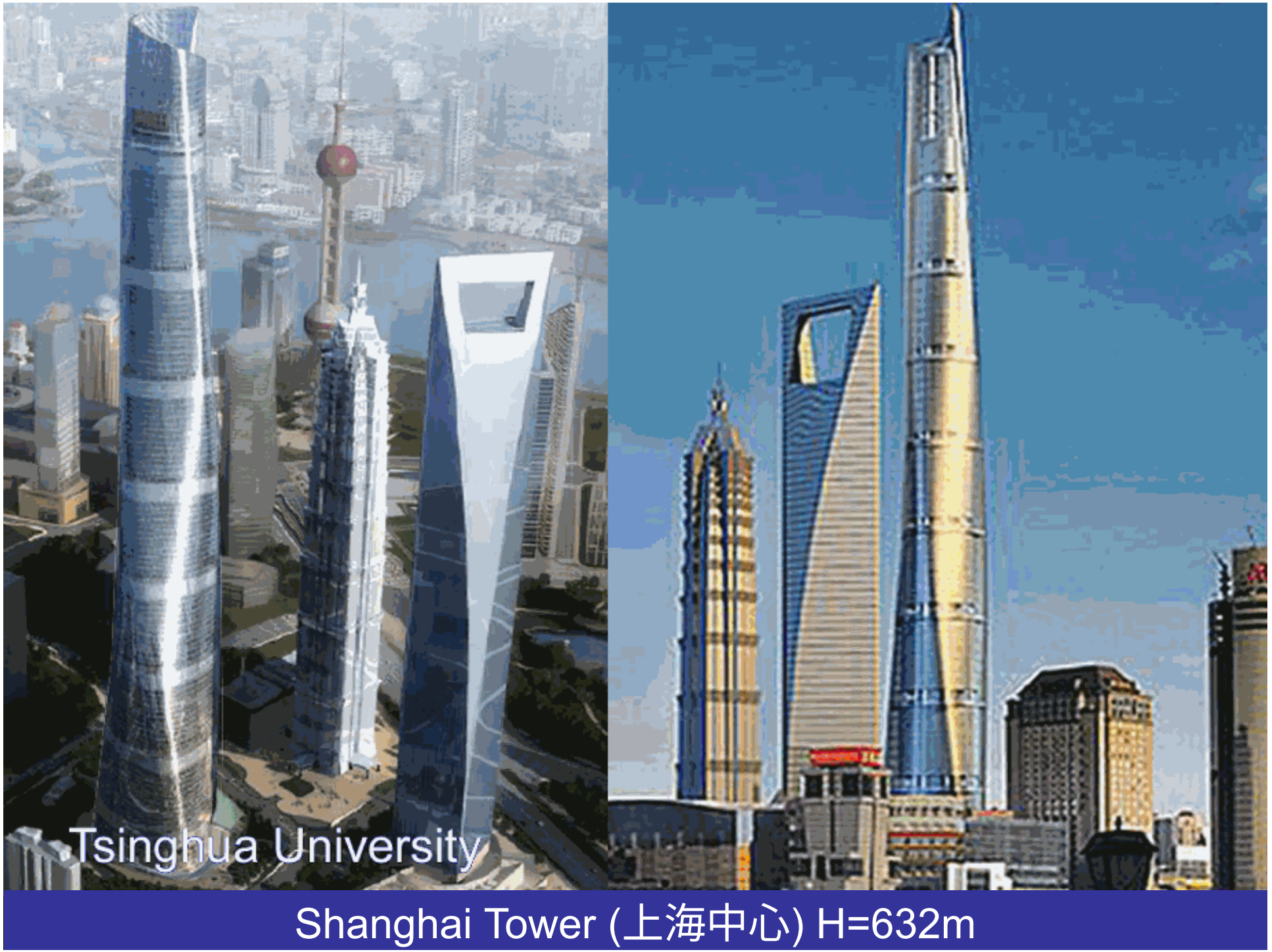




Collapse margin increased 15%



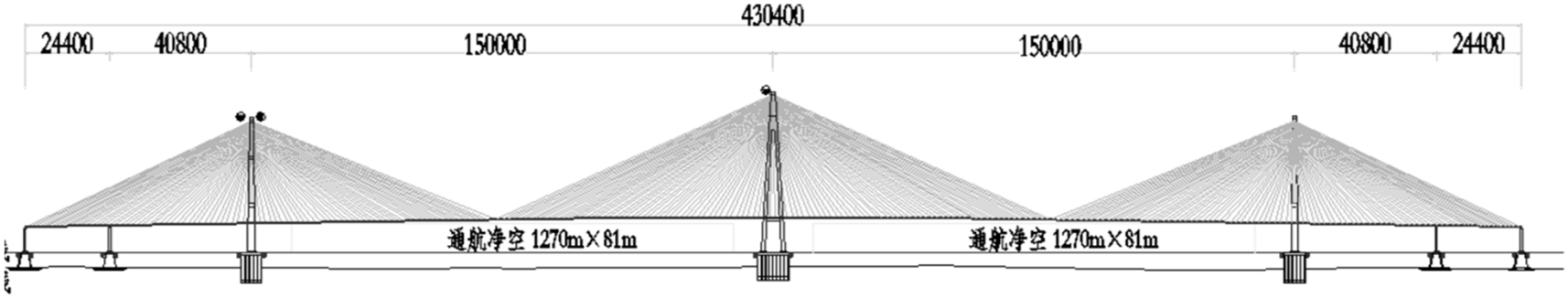
Material consumption reduced 11%
(84,338 ton)



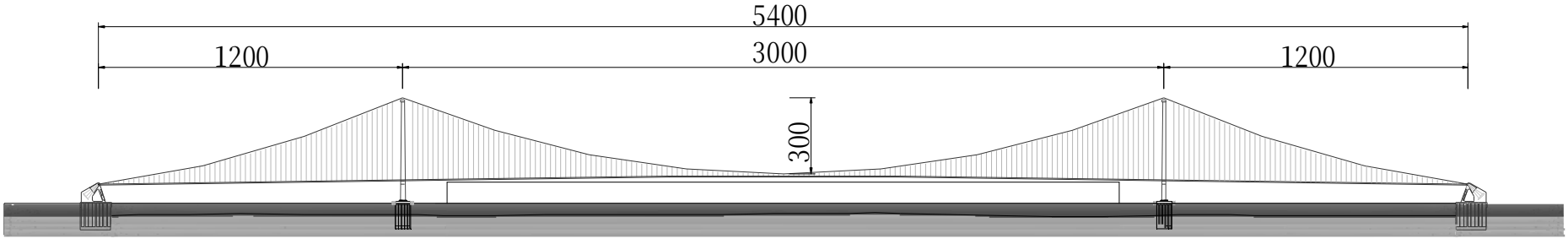
Shanghai Tower (上海中心) H=632m

Design of Qiongzhou Strait Bridge

- Two design schemes



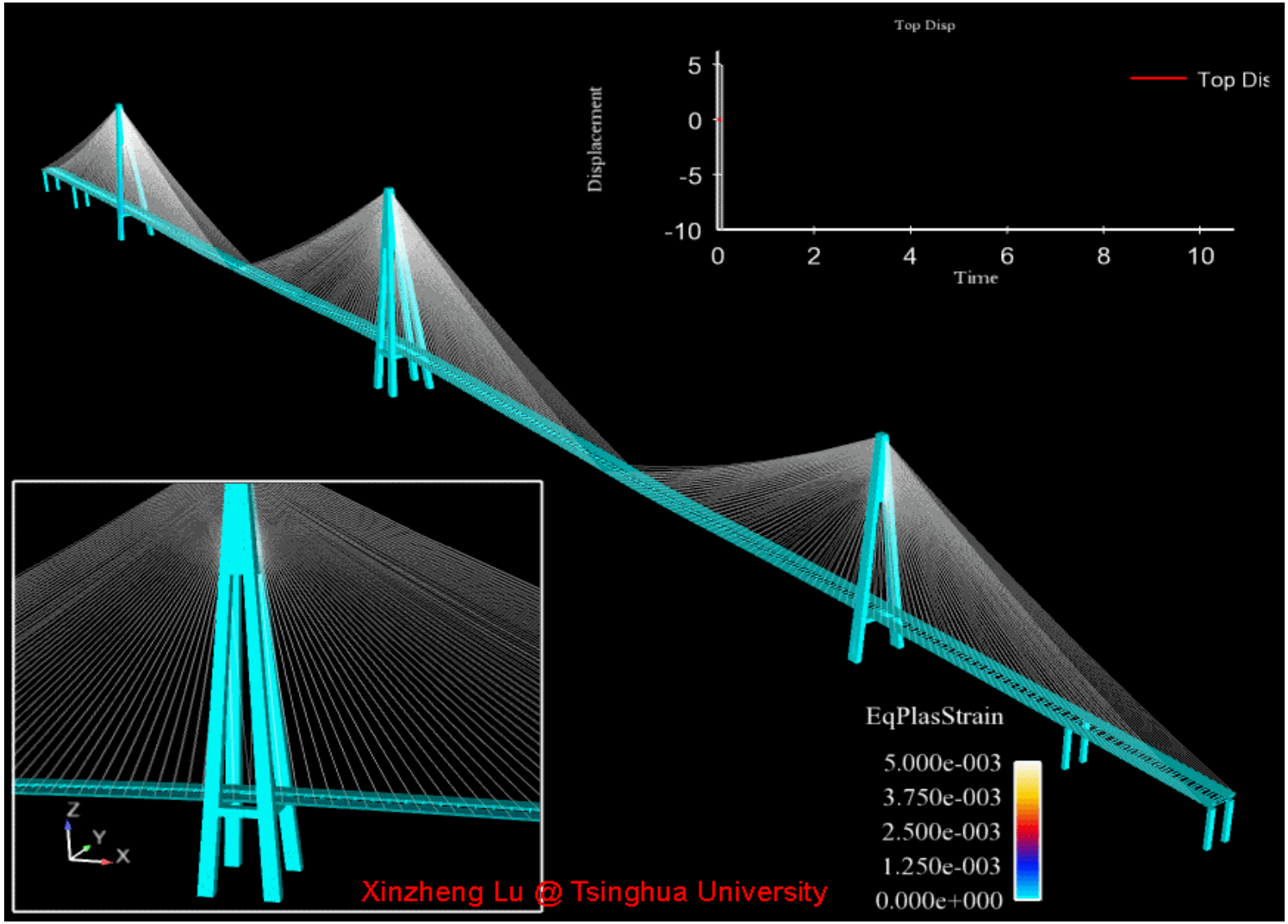
- Plan A: Total length=4304m / Main span=1500m



- Plan B: Total length=5400m / Main span=3000m

Design of Qiongzhou Strait Bridge

- Scenario simulation



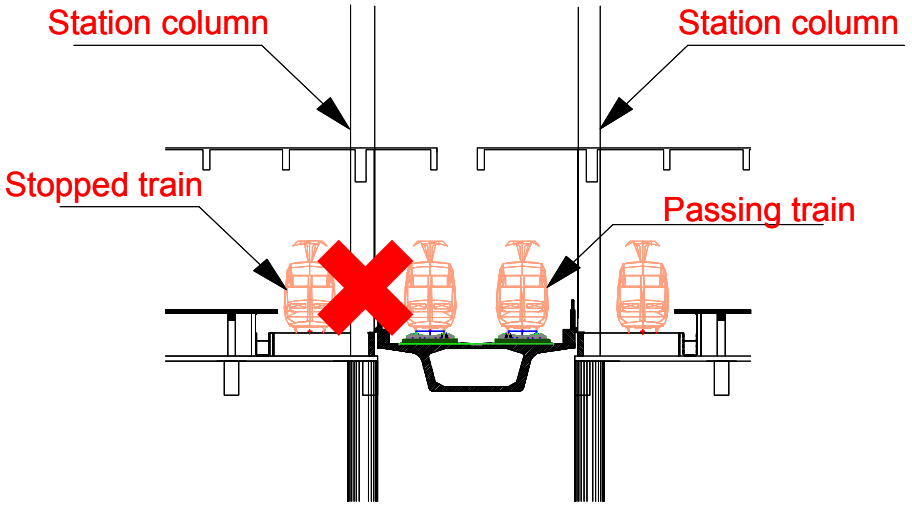
Design of Qiongzhou Strait Bridge

- Proposed engineering solution

Plan	Hazards	Evaluation results (Risk)
Plan A Cable stayed bridge √	Earthquake	16.05
	Ship collision	12.70
	Windstorm	…
Plan B Suspend bridge	Earthquake	22.62
	Ship collision	20.90
	Windstorm	…

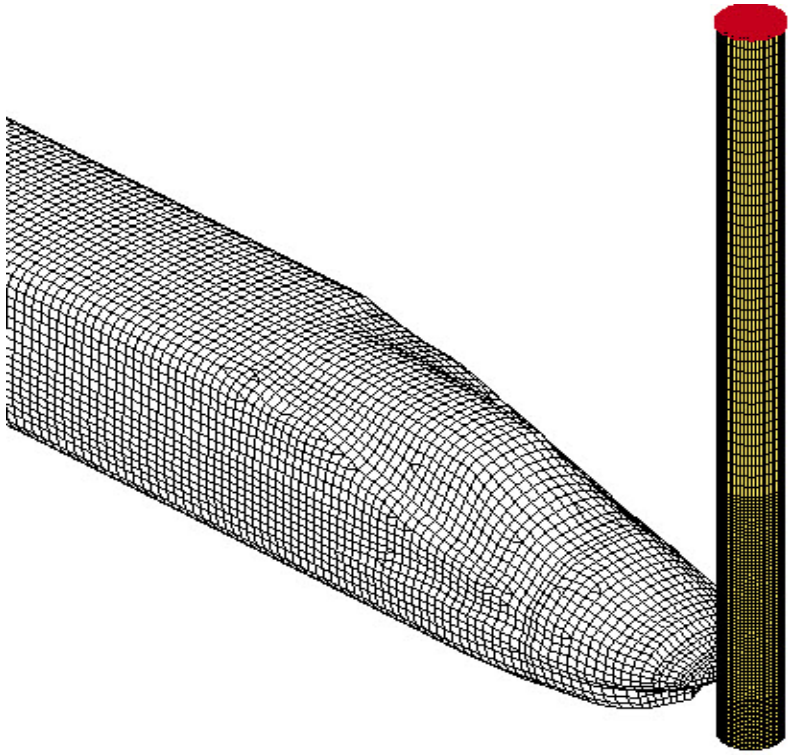
Collision of high-speed train to buildings

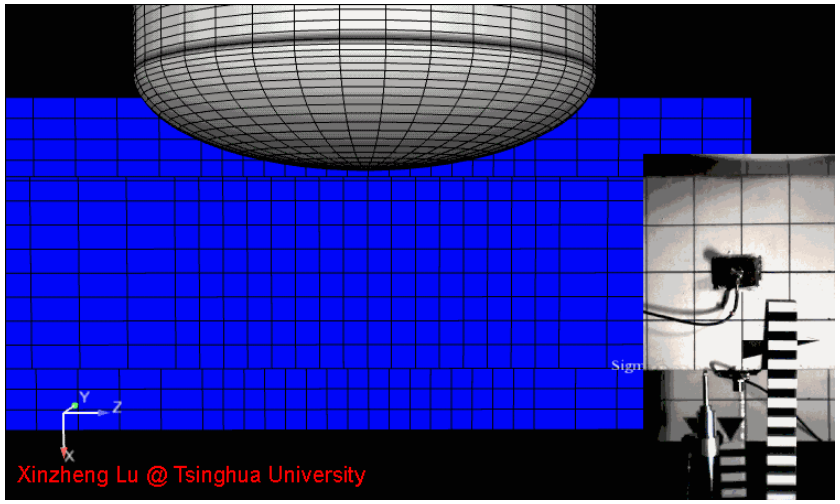
- China has the longest high-speed railway system in the world
- The speed of train passing the station is larger than 200km/h

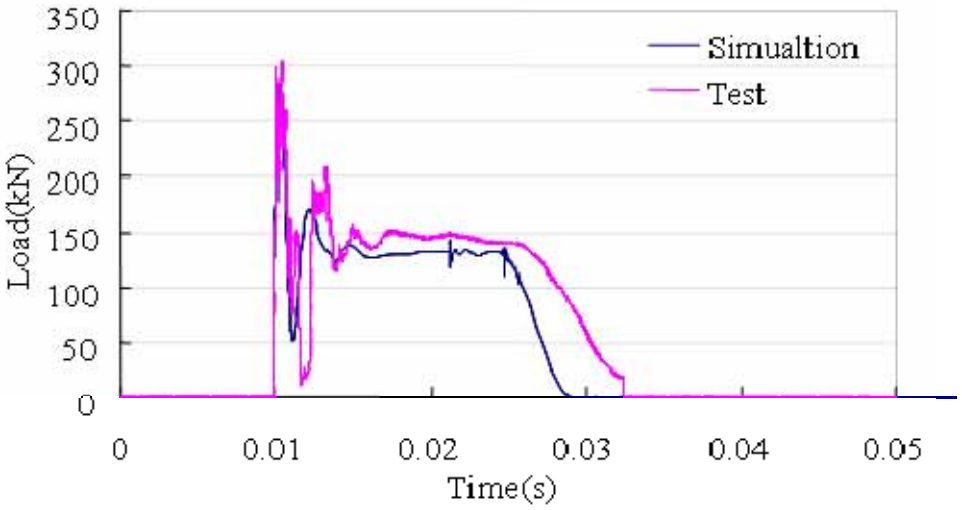


Collision of high-speed train to buildings

- Numerical model and Experimental validation

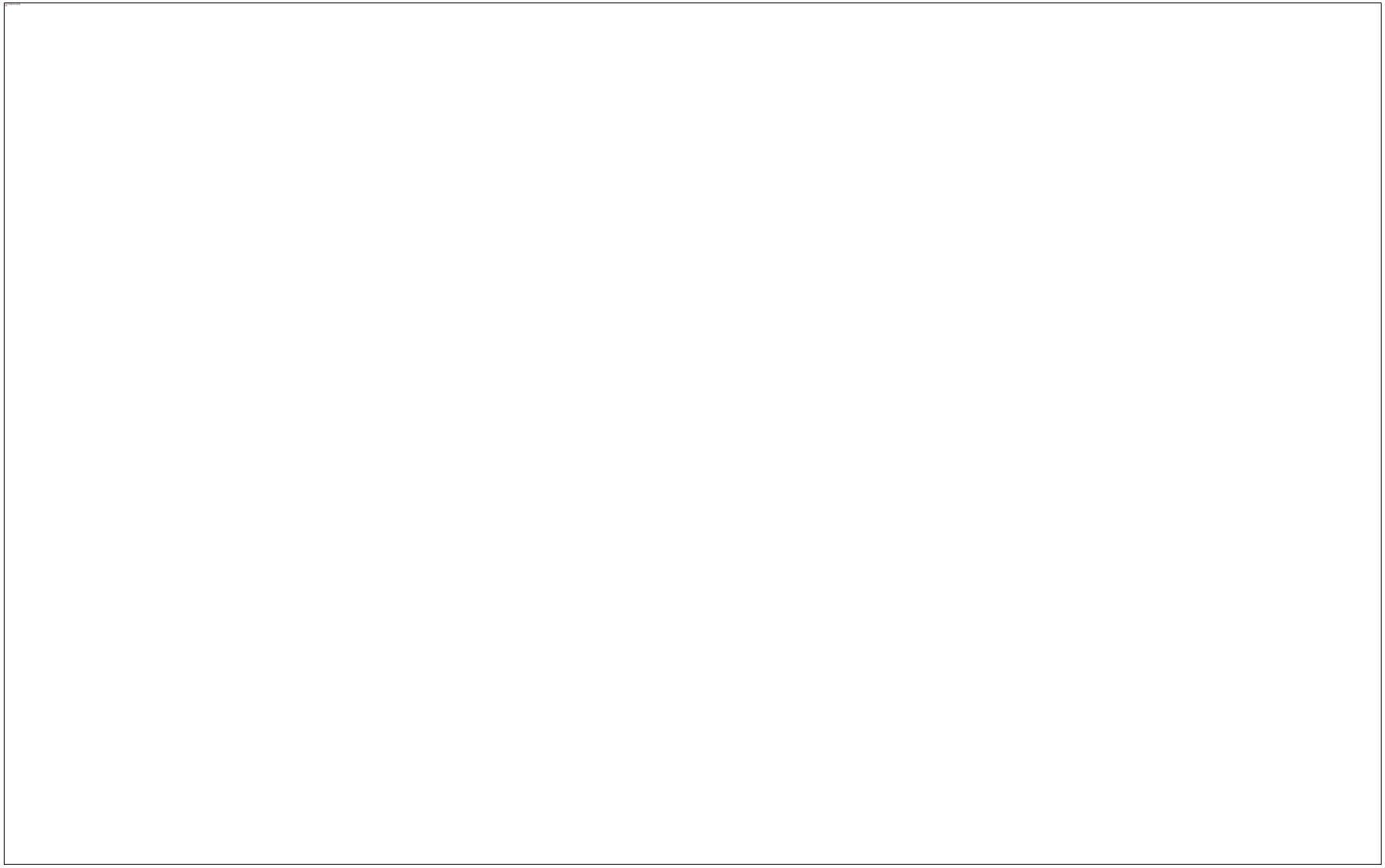






Collision of high-speed train to buildings

- Scenario simulation

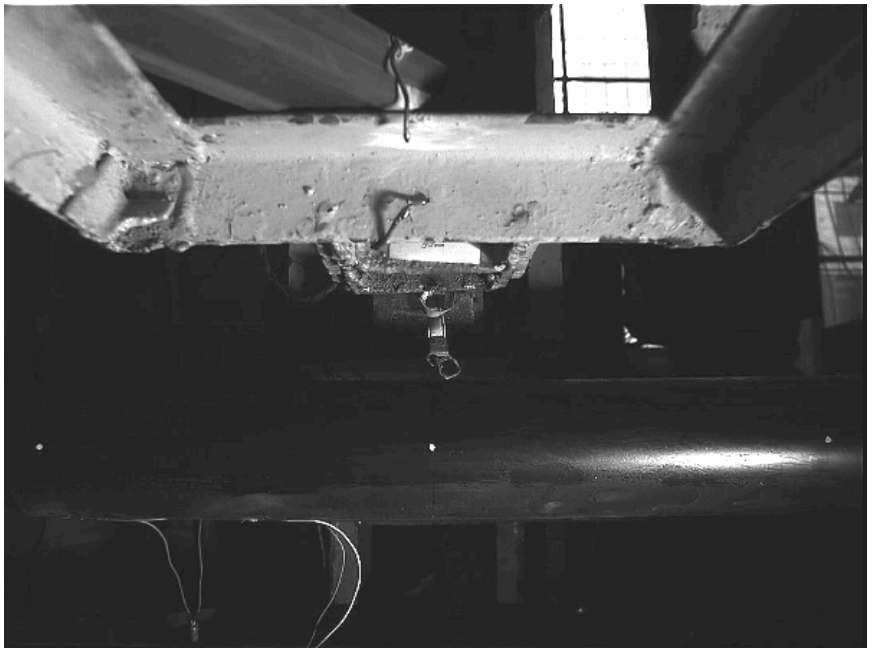


Collision of high-speed train to buildings

- Proposed engineering solution:

  Collision-proof columns

Conventional columns



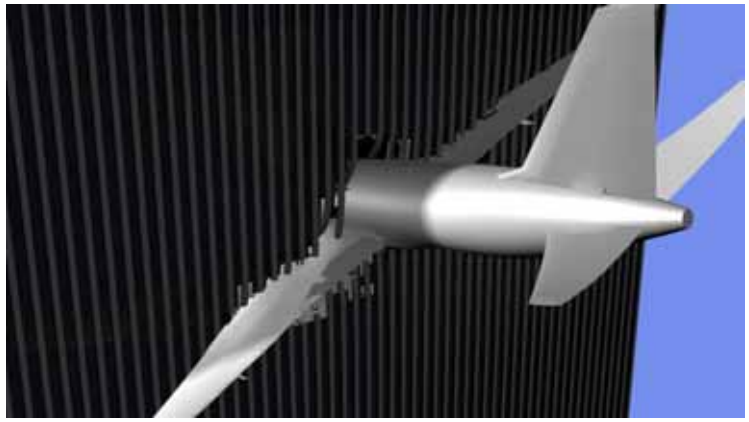
Collision-proof columns

Impact of airplane to NPP

1979 three mile island nuclear station

2011 Fukushinia Nuclear Power Plant

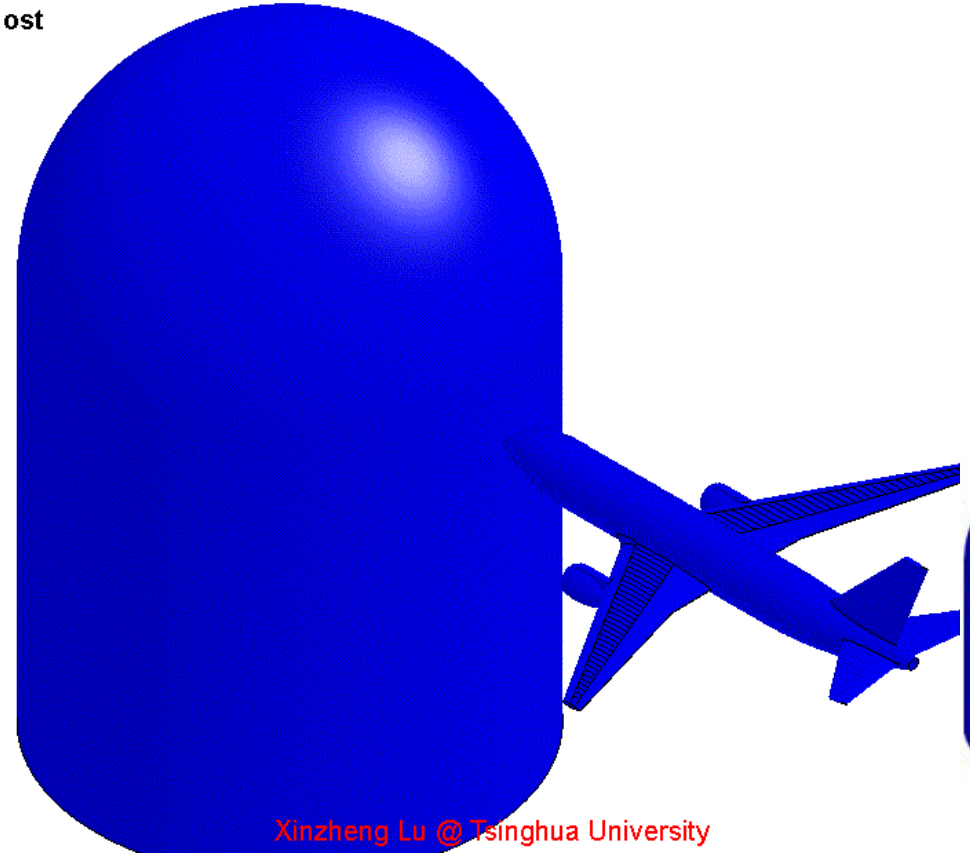
1986 Chernobyl Nuclear Power Plant

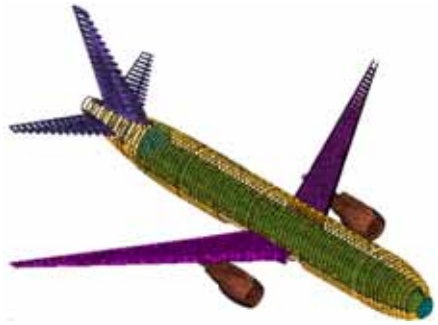


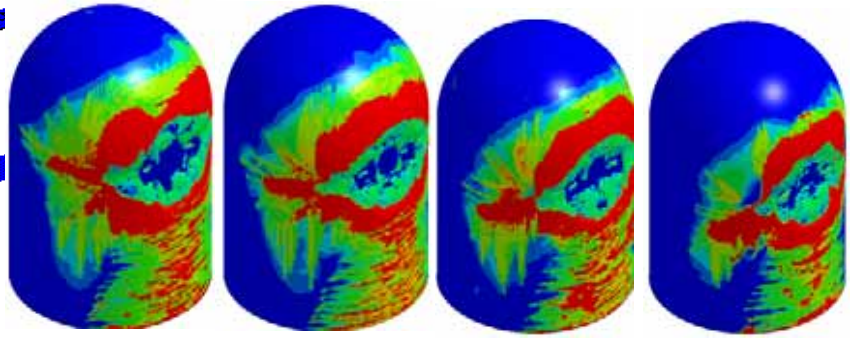
From Purdue University

Impact of airplane to NPP

- Numerical model and scenario simulation







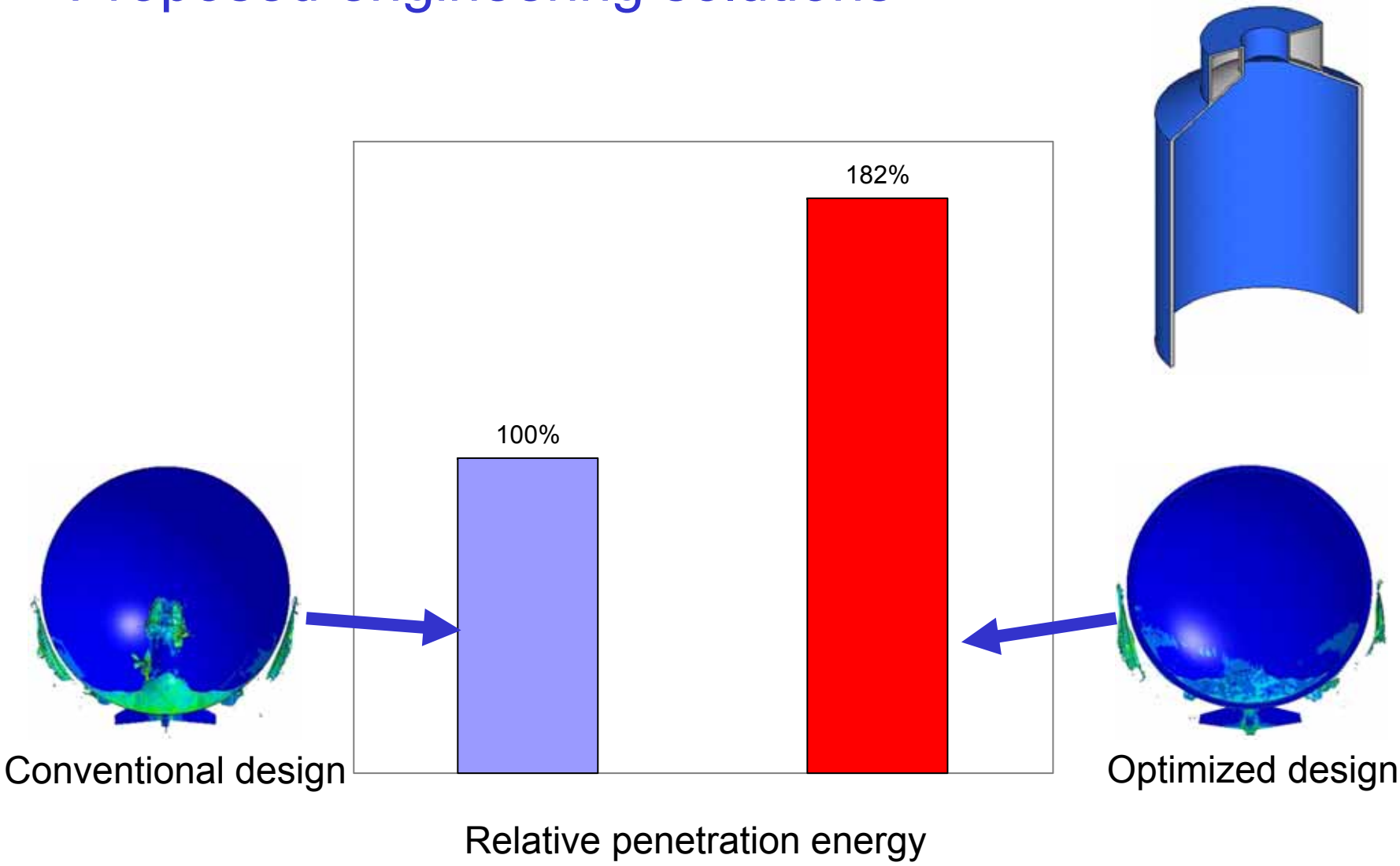
0 ° 15 ° 30 ° 45 °

Concrete damage (V=200 m/s; T=0.3 s)

Xinzheng Lu @ Tsinghua University

Impact of airplane to NPP

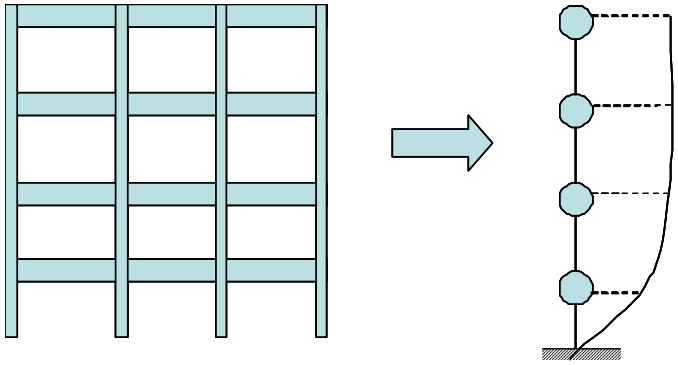
- Proposed engineering solutions

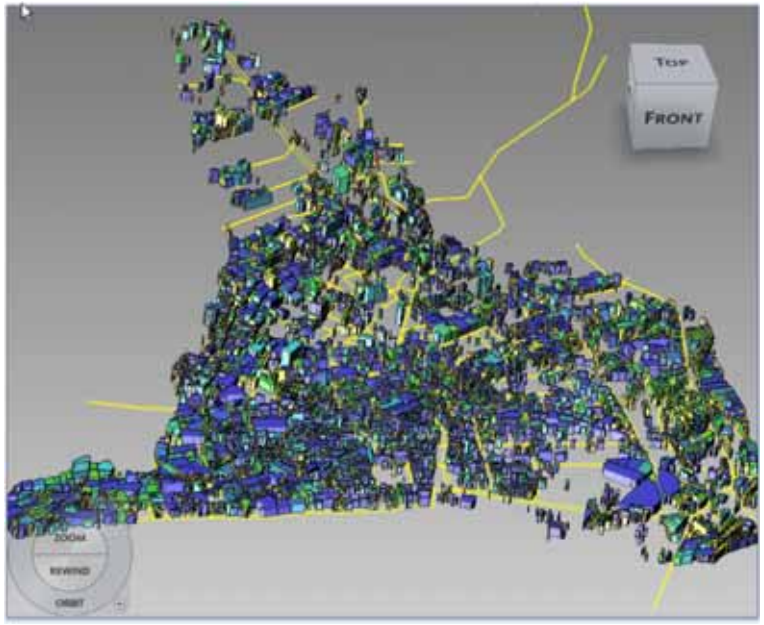


Seismic disaster prediction for cities

Seismic disaster prediction for cities

- Numerical models





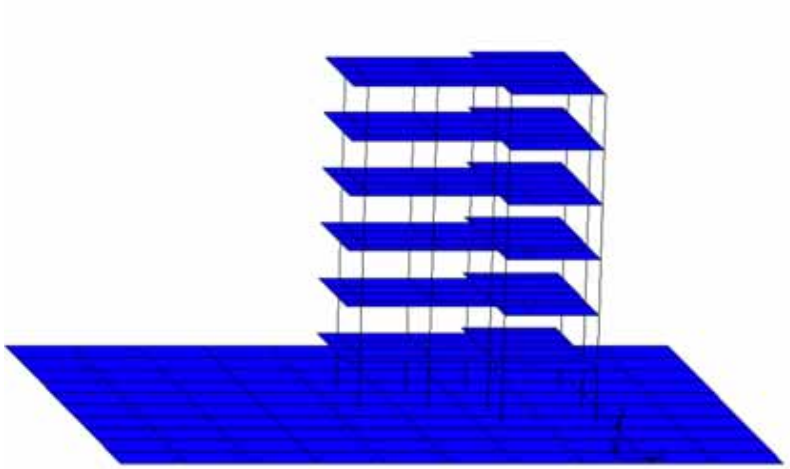
GIS

Computing model

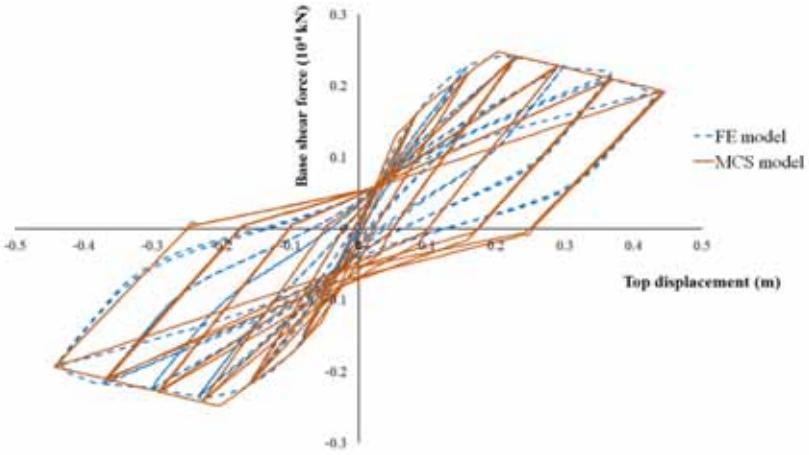
Lu XZ, et al, A coarse-grained parallel approach for seismic damage simulations of urban areas based on refined models and GPU/CPU cooperative computing, *Advances in Engineering Software*, 2014

Seismic disaster prediction for cities

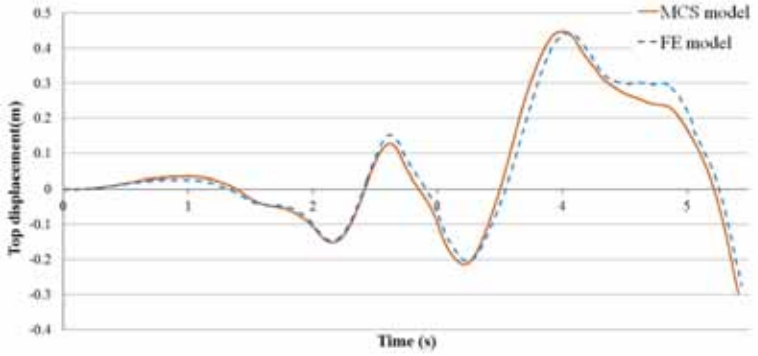
- Model validation



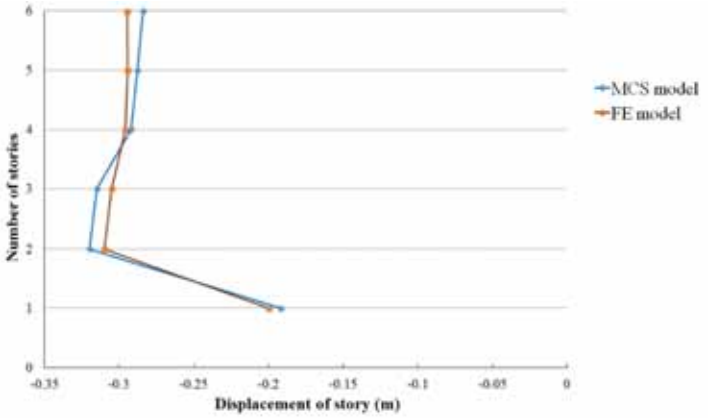
Refined FE model



Inter-story hysteretic model



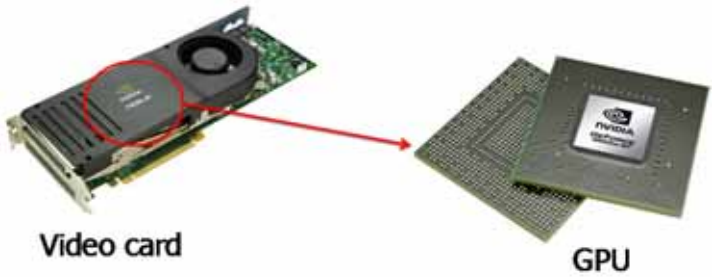
Top displacement

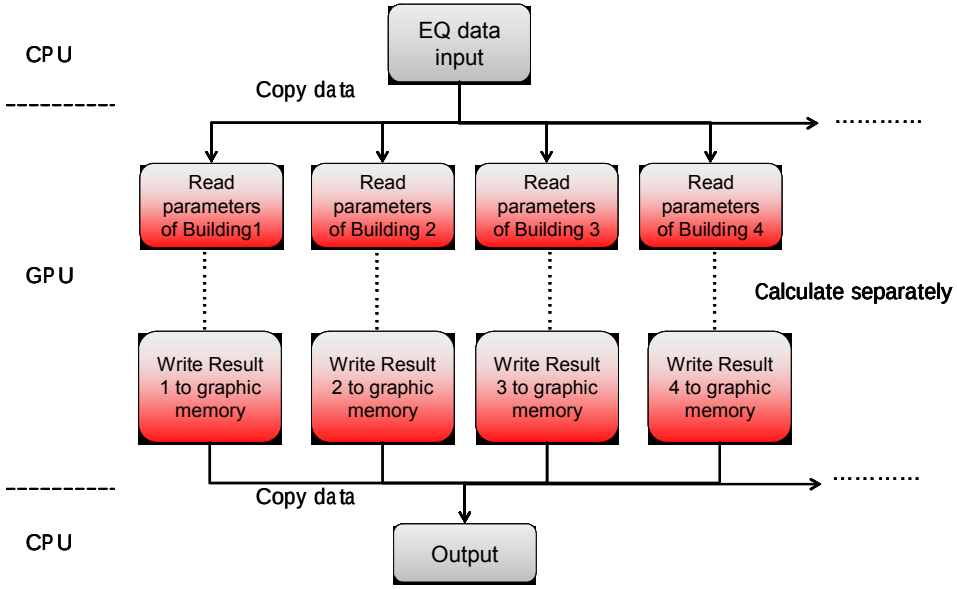


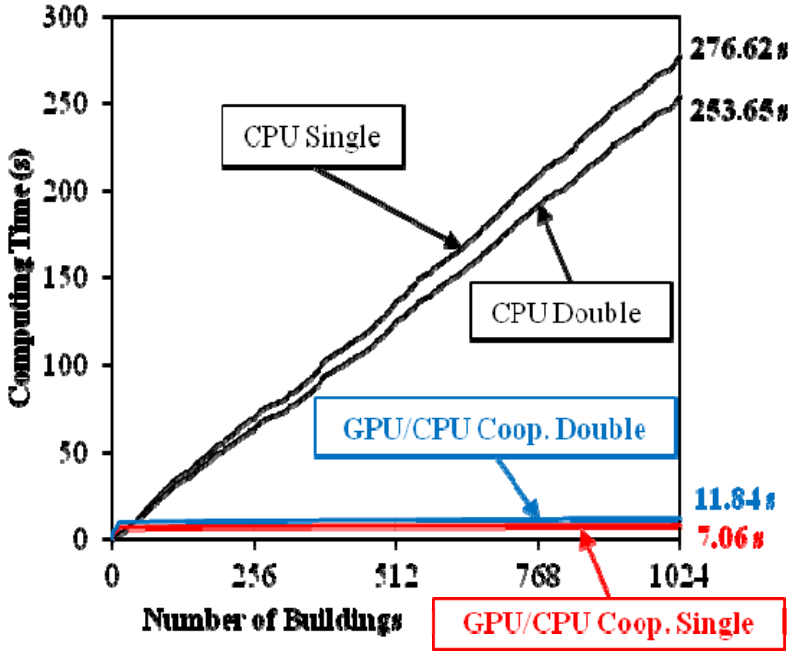
Inter-story drift

Seismic disaster prediction for cities

- GPU (Graphic Processing Unit) based high performance computing







39x of speedup

Seismic disaster prediction for cities

清華大學
Tsinghua University

Seismic disaster prediction for cities

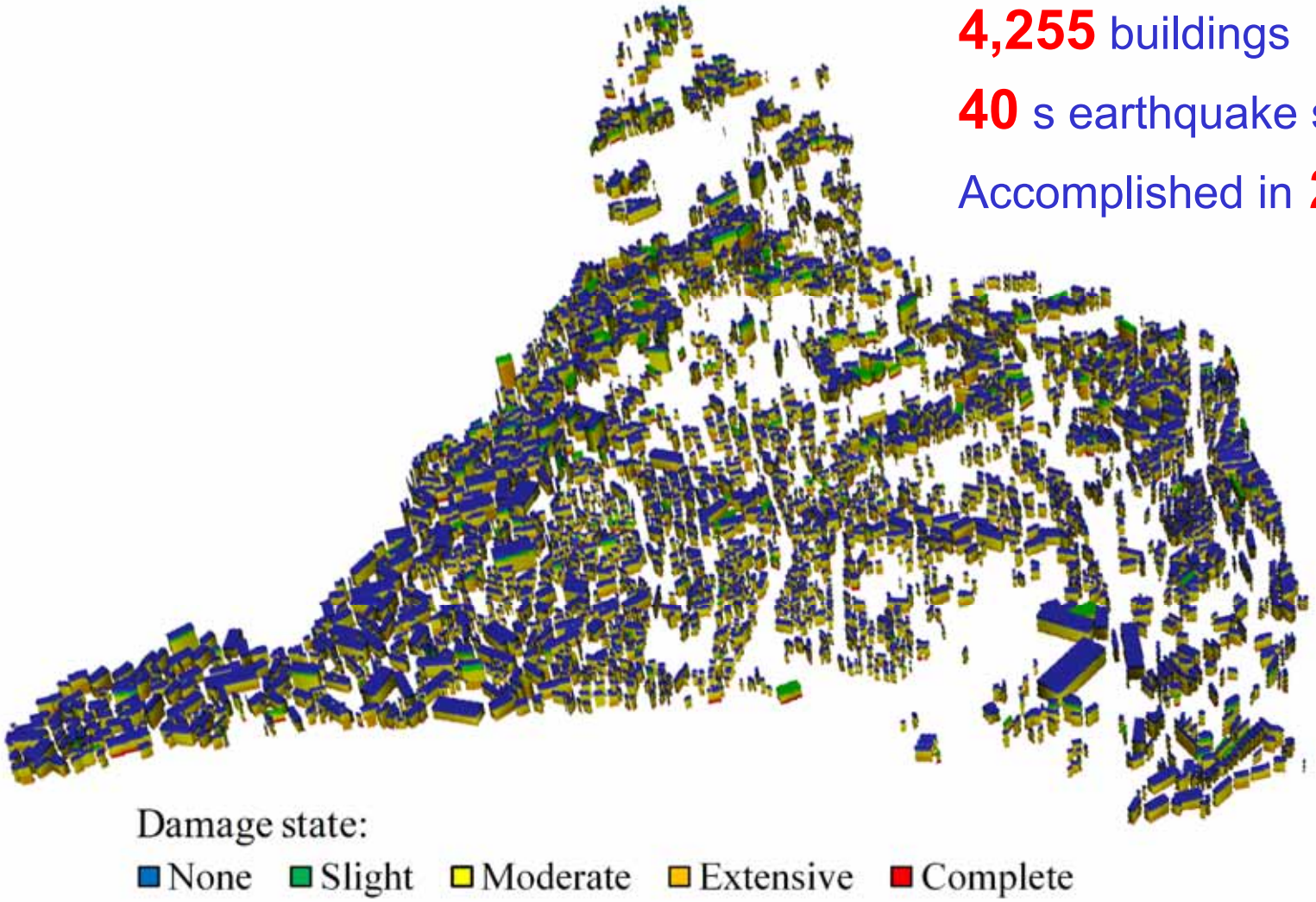
- Scenario simulation

Desktop Computer

4,255 buildings

40 s earthquake simulation

Accomplished in **216** s



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Seismic disaster prediction for cities

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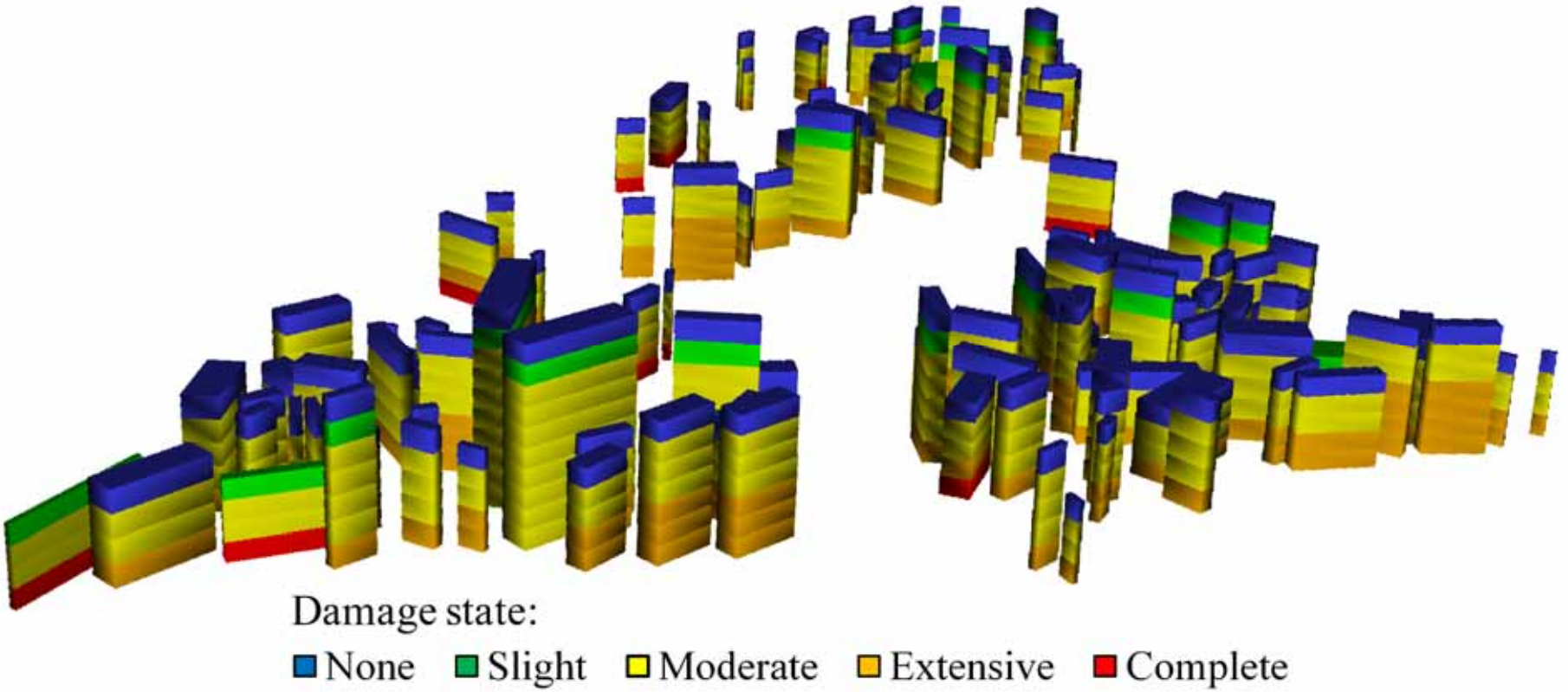

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Seismic disaster prediction for cities

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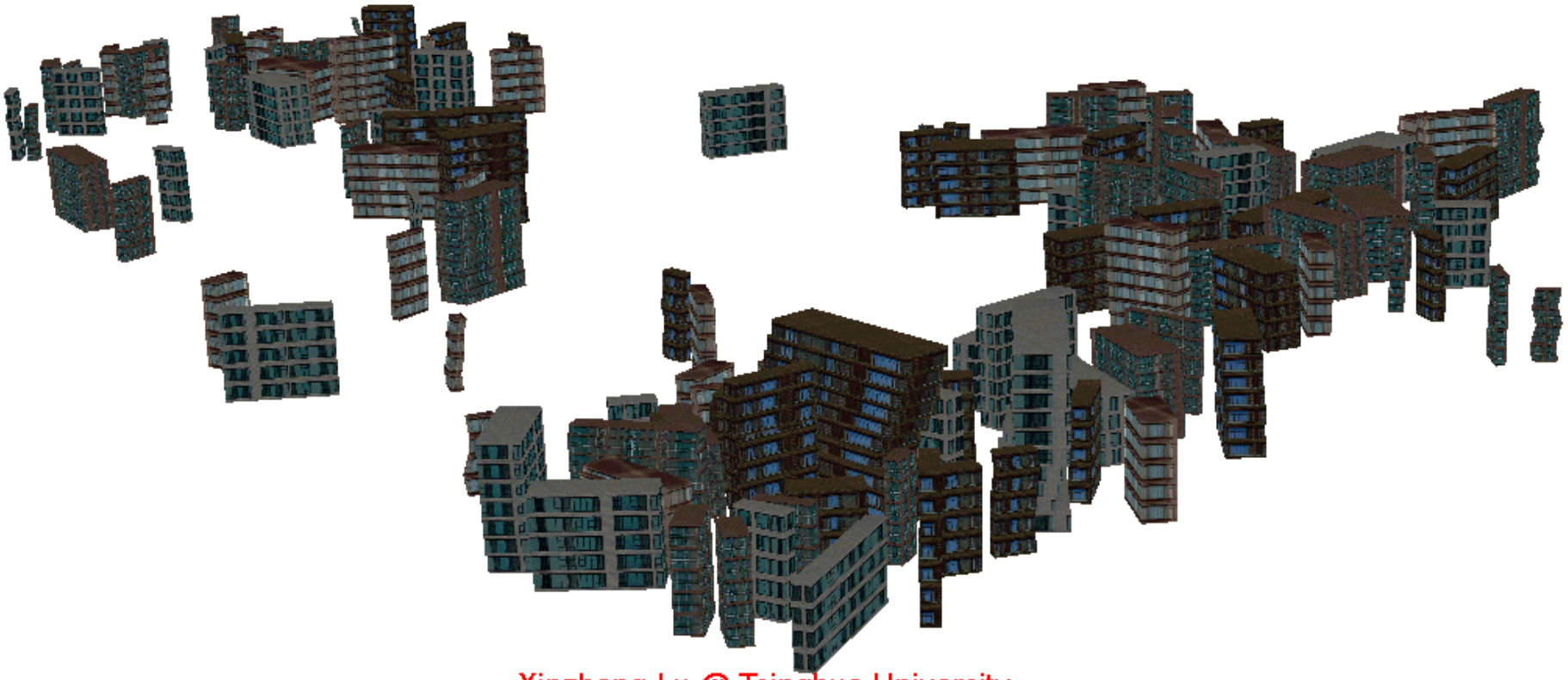


Xu Z, Lu XZ, Guan H, Han B, Ren AZ, Seismic damage simulation in urban areas based on a high-fidelity structural model and a physics engine, *Natural Hazards*, 2014

Conclusions

清華大學 Tsinghua University

Scenario Simulation and Engineering Solution for Extreme Disasters

Numerical model	Science
Experimental validation	Technology
Design methodology	Engineering
Computational algorithm	Mathematic

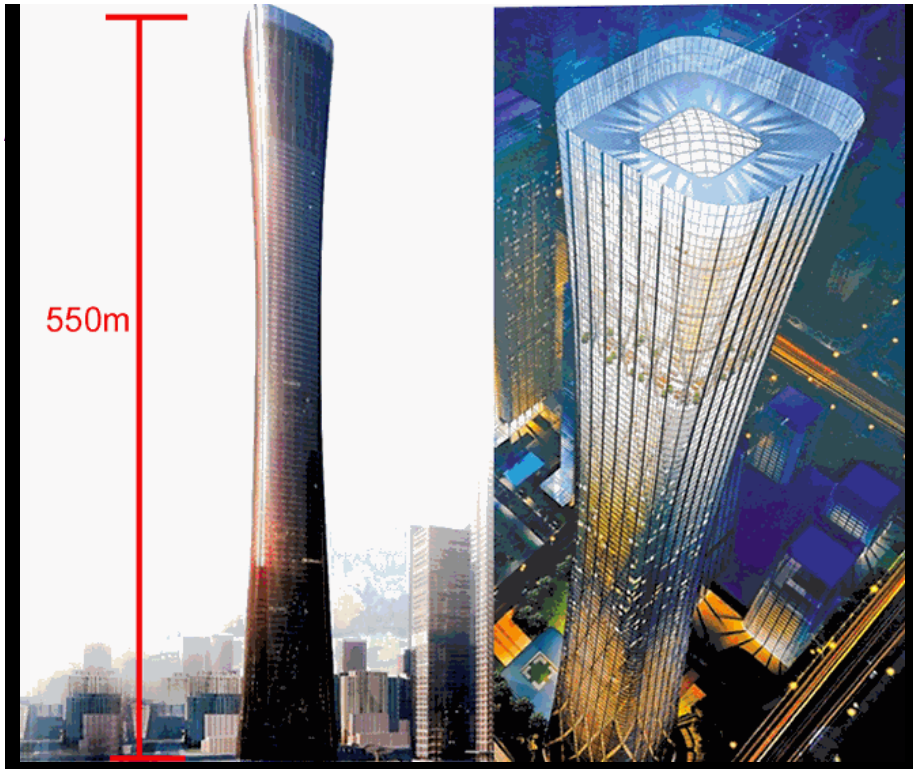
Conclusions

Scenario Simulation

Engineering Solution

Human resilience	Knowing what may happen, how to respond
Recovery government	Provide vision, leadership, service, information
Infrastructure resilience	Ability to return to full occupancy and function

Resilient community



Thank you for your attention!

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