NANYANG TECHNOLOGICAL UNIVERSITY

Earthquake Disaster Mitigation Programs in Asia

presented by

Li Bing
School of Civil and Environmental Engineering

NTU – Why the focus on Asia

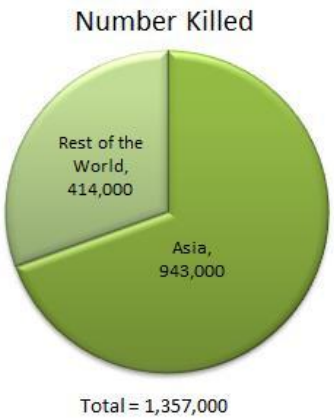
- Asia has the largest growth of real assets and urban centers on Earth. This has exacerbated the problems of Catastrophe Risks.
- Asia is home to the largest number of 'poor' people of the world.
- Historically, Asia has suffered the most due to catastrophic events, but has the least amount of safety net or risk transfer mechanisms.
- Climate Change issues will potentially impact Asia more than any other continent.
- Catastrophe insurance penetration is extremely low in developing countries in Asia (eg under 0.5% in India, Philippines and China).

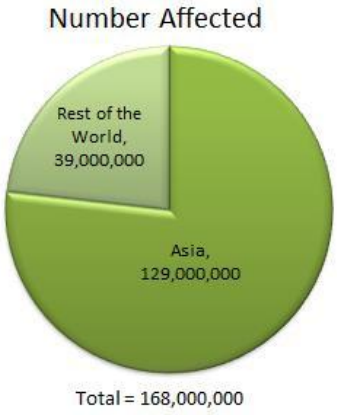
Top 15 Urban Conglomerates (2012)

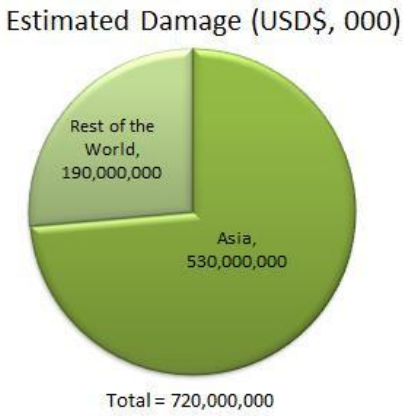
1.	Tokyo	Japan	Asia	34,400,000
2.	Canton	China	Asia	25,600,000
3.	Seoul	Korea (South)	Asia	25,300,000
4.	Shanghai	China	Asia	25,100,000
5.	Mexico City	Mexico	North America	23,100,000
6.	Delhi	India	Asia	22,900,000
7.	New York	USA	North America	22,000,000
8.	São Paulo	Brazil	South America	21,000,000
9.	Bombay	India	Asia	20,700,000
10.	Manila	Philippines	Asia	20,500,000
11.	Jakarta	Indonesia	Asia	18,800,000
12.	Los Angeles	USA	North America	18,100,000
13.	Karachi	Pakistan	Asia	17,200,000
14.	Osaka	Japan	Asia	16,800,000
15.	Beijing	China	Asia	16,300,000

NANYANG TECHNOLOGICAL UNIVERSITY

Earthquake Loss of Asia (1960-2011)





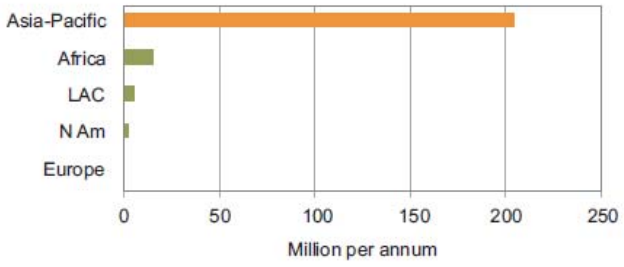


NANYANG TECHNOLOGICAL UNIVERSITY

Source: EM-DAT: The OFDA/CRED International Disaster Database
Université Catholique de Louvain, Brussels, Belgium (www.emdat.be)

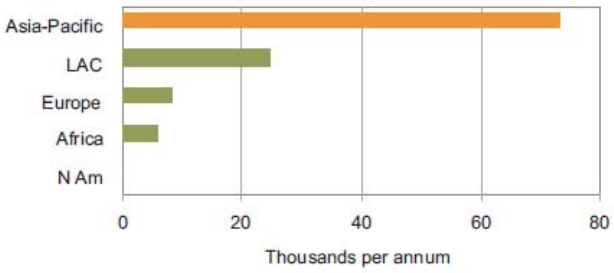
World – Natural Disasters (2001-2010)

People affected



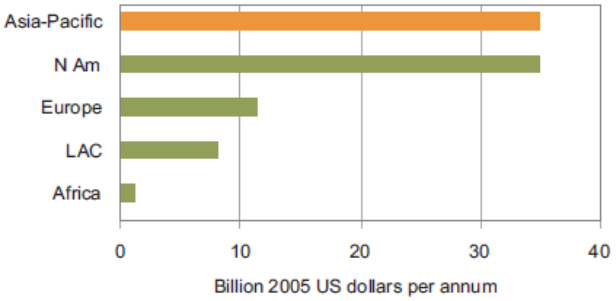
Average annual population affected by natural disasters, World regions, 2001-2010

People killed



Average annual population killed by natural disasters, World regions, 2001-2010

Economic damages



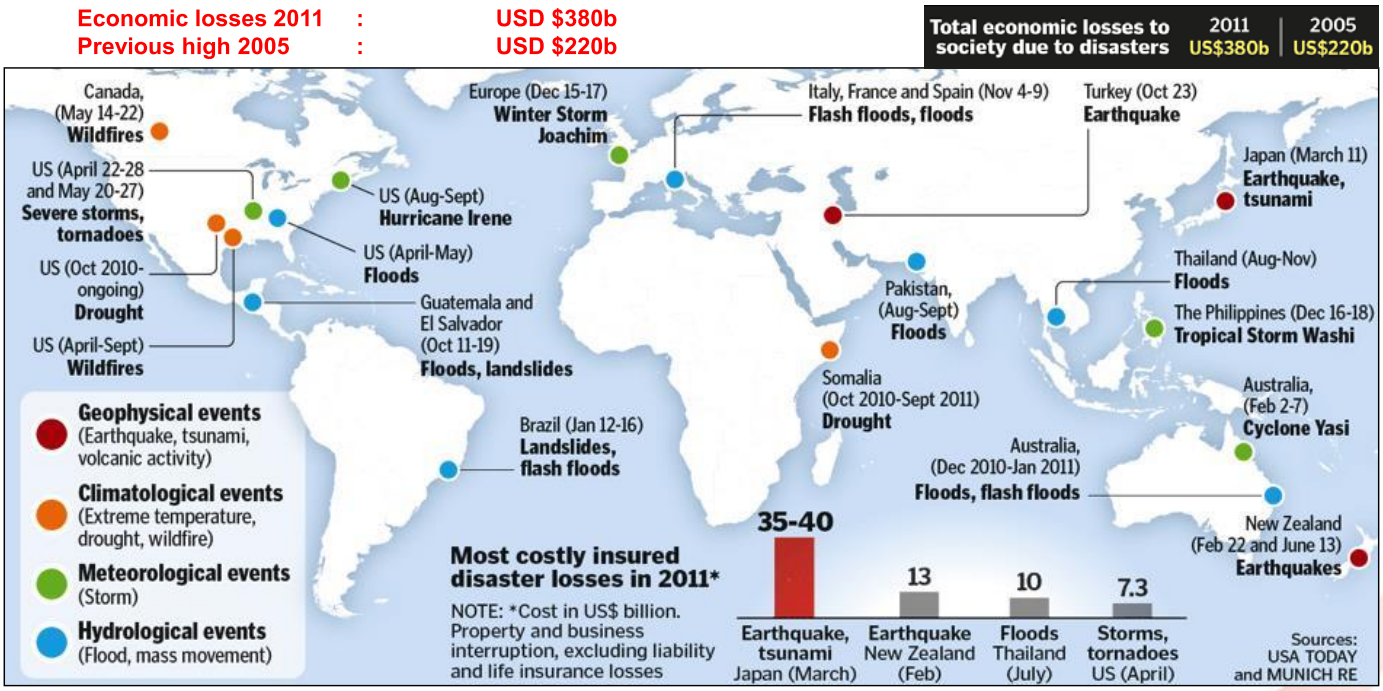
Average annual economic damage for natural disaster, World regions, 2001-2010

Asia and Pacific countries continue to suffer disproportionately from disasters caused by natural hazards

UNESCAP - Statistical Yearbook for Asia and the Pacific 2011
Data source: EM-DAT Emergency Events Database

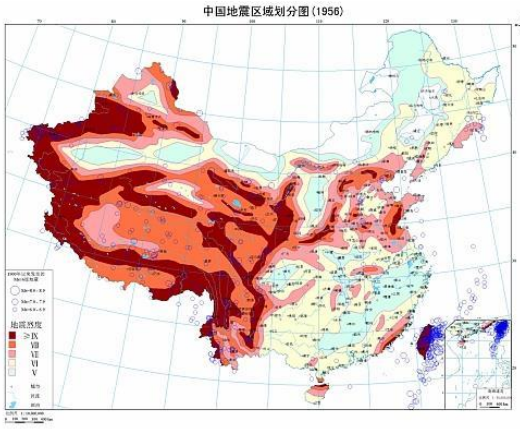
World – Natural Disasters 2011

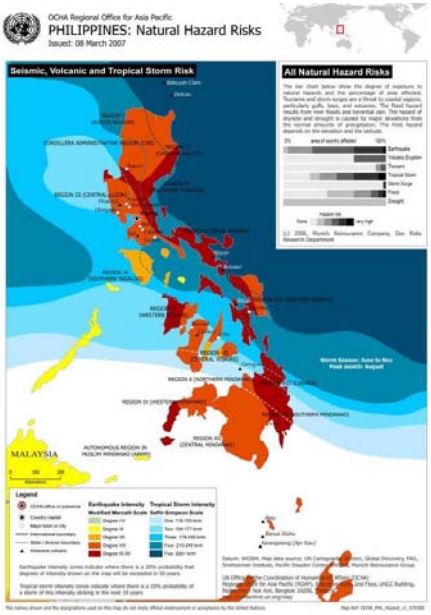
Economic losses 2011 : USD $380b
Previous high 2005 : USD $220b



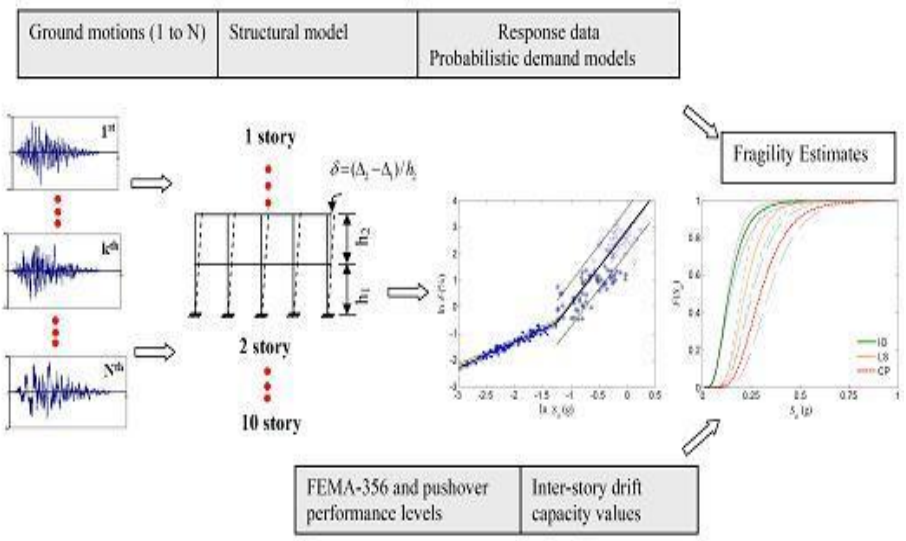
Source: Straits Times news, published on 6th Jan ' 12

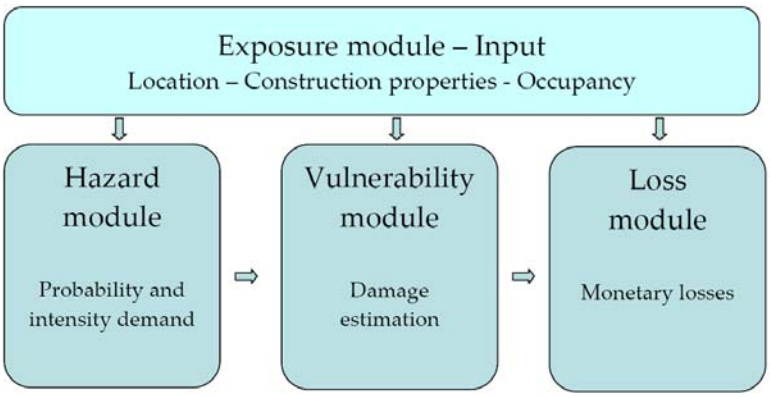
Earthquakes





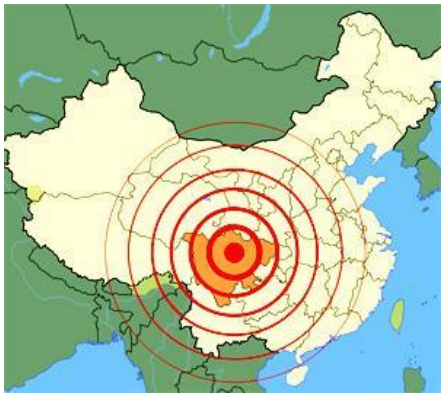
- Earthquakes result in disasters due to damage or collapse of buildings and other man-made structures.
- Earthquake impact depends on:
  - intensity,
  - duration and frequency content of ground motion,
  - geologic and soil condition,
  - construction materials and the quality of construction.





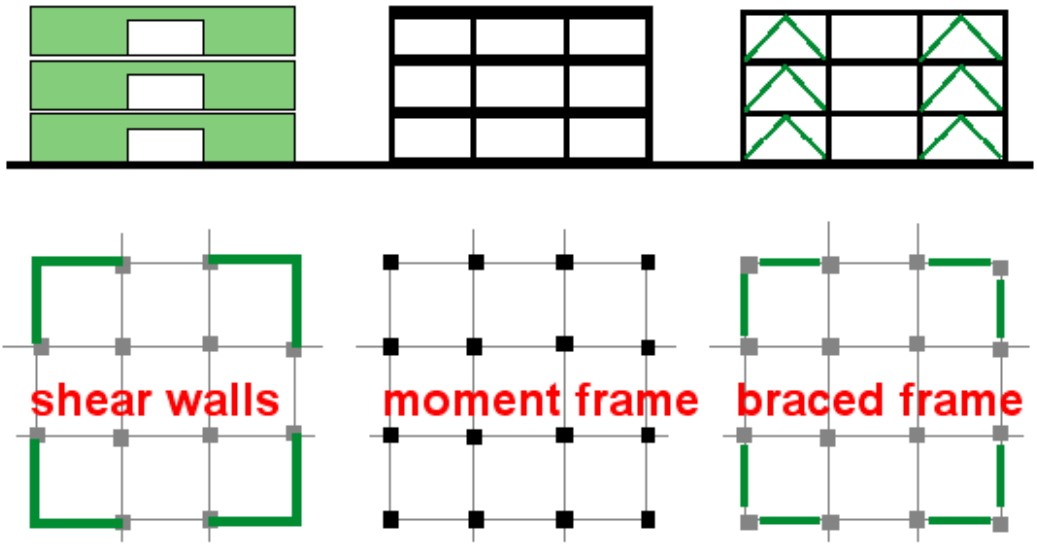
Causes for Failure of Buildings during Earthquakes

- Damage to load-bearing walls
- Doors and window openings
- Failure of ground
- Failure of roofs and floors
- Failure of columns and beam-column joints
- Material and Workmanship



LATERAL FORCE RESISTING SYSTEMS

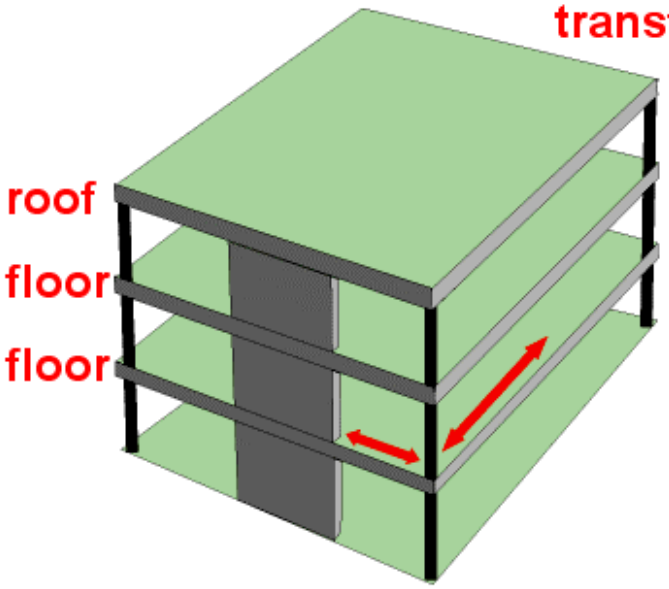
basic types



They tend to be mutually exclusive-that is, it is desirable not to mix the systems in a single building because of the different strength and stiffness characteristics of the systems.

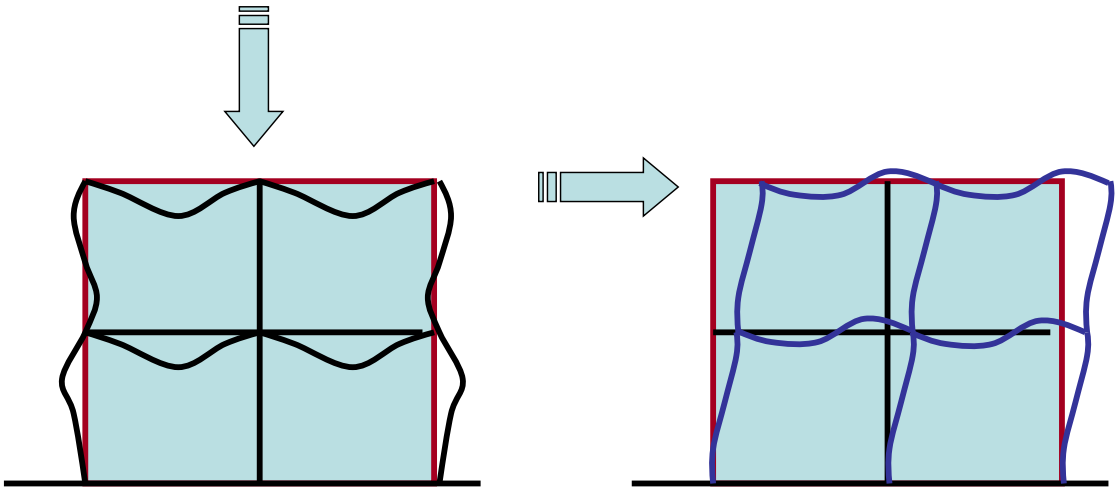
DIAPHRAGMS

the roof and floor structures
transfer the lateral forces
to the columns and
shear walls



Together with the vertical lateral- force-resisting system, diaphragms form a horizontal system that connects together the vertical elements and carries their loads down to the foundation

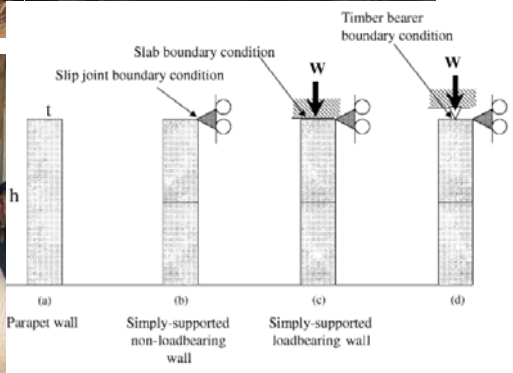
The reinforced concrete slab is the most useful discovery for supporting lateral loads in buildings



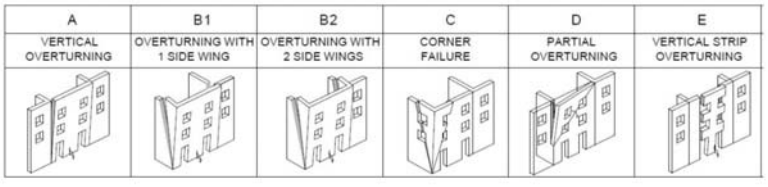
Gravity Load ***Lateral Loading***

NANYANG TECHNOLOGICAL UNIVERSITY

Prevention measures



- To withstand quakes, building design must ensure that it has adequate strength and ductility, and it functions as one unit when subjected to large deformation caused by ground motion:
  - Implement earthquake resistant technologies
  - Follow building codes during construction of new structures.
  - Strengthening and retrofitting of existing buildings
  - Training and capacity building of construction professionals and local builders



NANYANG TECHNOLOGICAL UNIVERSITY

NANYANG TECHNOLOGICAL UNIVERSITY

NANYANG TECHNOLOGICAL UNIVERSITY

Projects

- Development of wall bracing in Yunnan, China

Wire Mesh

Training & Education

Existing damaged housing

NANYANG TECHNOLOGICAL UNIVERSITY

Projects

- Development of wall bracing in Agam, Indonesia at a local Polyclinic

Wall bracing

Installing strips on wall

Better seismic detailing

NANYANG TECHNOLOGICAL UNIVERSITY

Projects

- Seismic strengthening and retrofitting of schools in China

Strengthening of walls, beams and columns

Temporary Classroom

Retrofitting of existing buildings

NANYANG TECHNOLOGICAL UNIVERSITY

Outreach

- Ecoventure at Chongqing

Strengthening and retrofitting of buildings

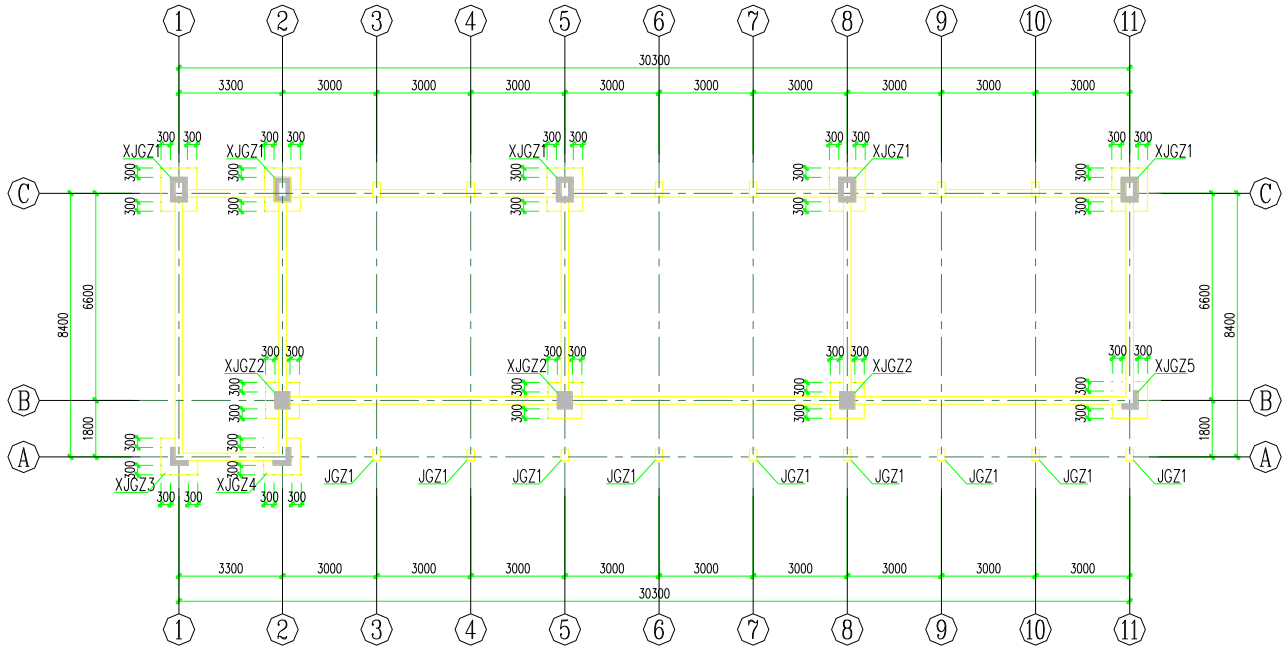
- Strengthening procedures should aim at the following objectives:
  - Increasing lateral strength by reinforcement or by increasing the number of walls and columns.
  - Giving unity to the structure by providing a proper connection between its resisting elements.
  - Strengthening the connections between roofs or floors and walls, between intersecting walls, between walls and foundations and the beam-column joints.
  - Eliminating stress concentrations in some structural members by symmetrical distribution of resisting members.
  - Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members.

NANYANG TECHNOLOGICAL UNIVERSITY

(i) Strengthening Framing Members

- The framing members may be strengthened by using steel jackets around beams and columns
- The connection between the jacket and concrete is accomplished by anchors.
- The anchors may be secured to existing RC parts mechanically or by using epoxy or expansive grout.
- Parapets, infill walls and veneers can be secured to the framing using ties.

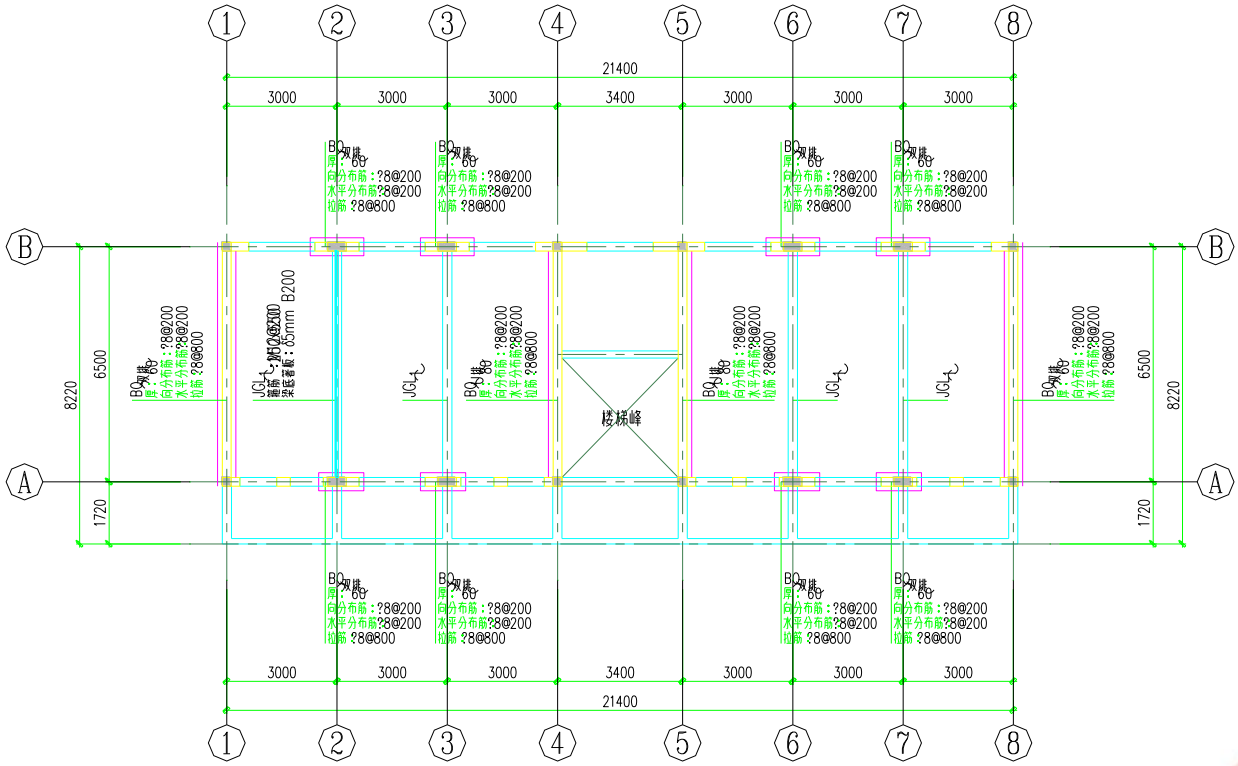
NANYANG TECHNOLOGICAL UNIVERSITY



XJGZ（新加构造柱）基础平面布置图 1:100

（基础埋深＞1500mm）

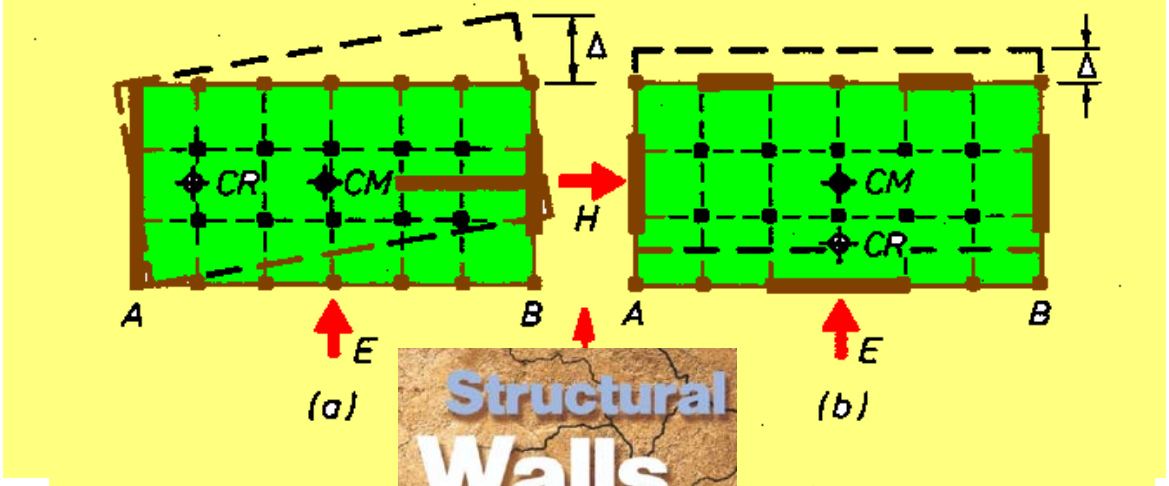
Strengthening details

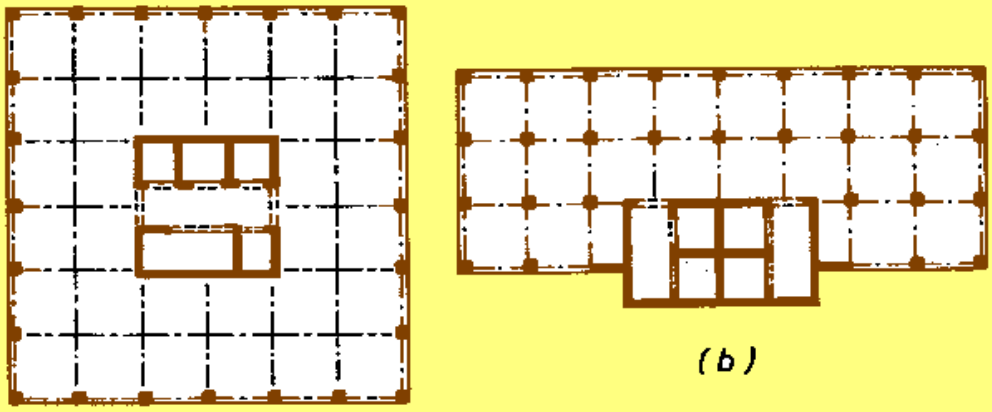


基顶-7.200m墙体加固平面图 1:100

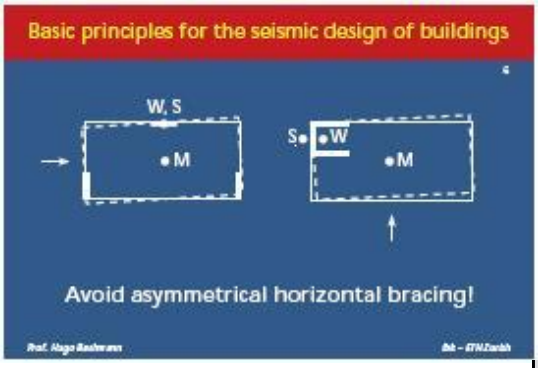
3.600、7.200m梁加固平面图

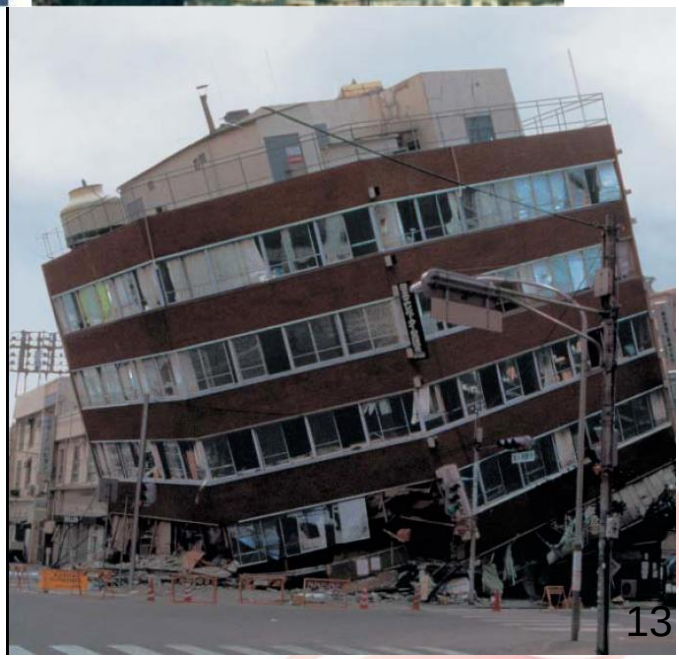
Strengthening details





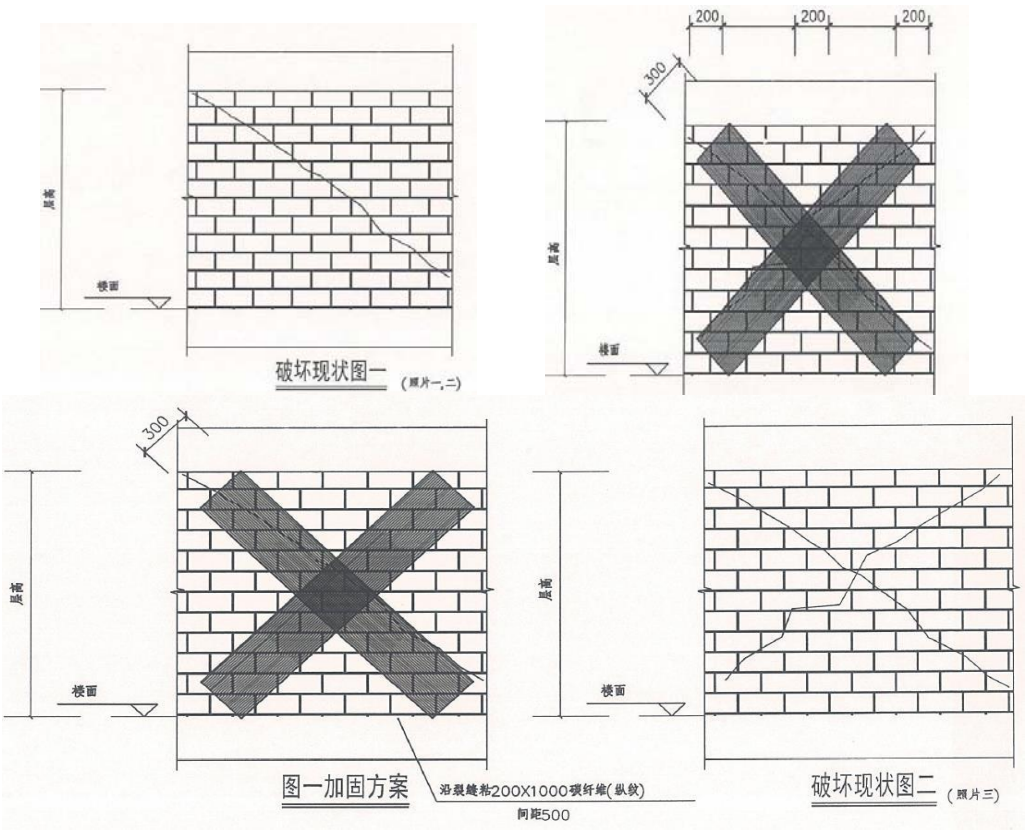
Lateral force resistance provided by reinforced concrete cores





(ii) Bracing masonry walls

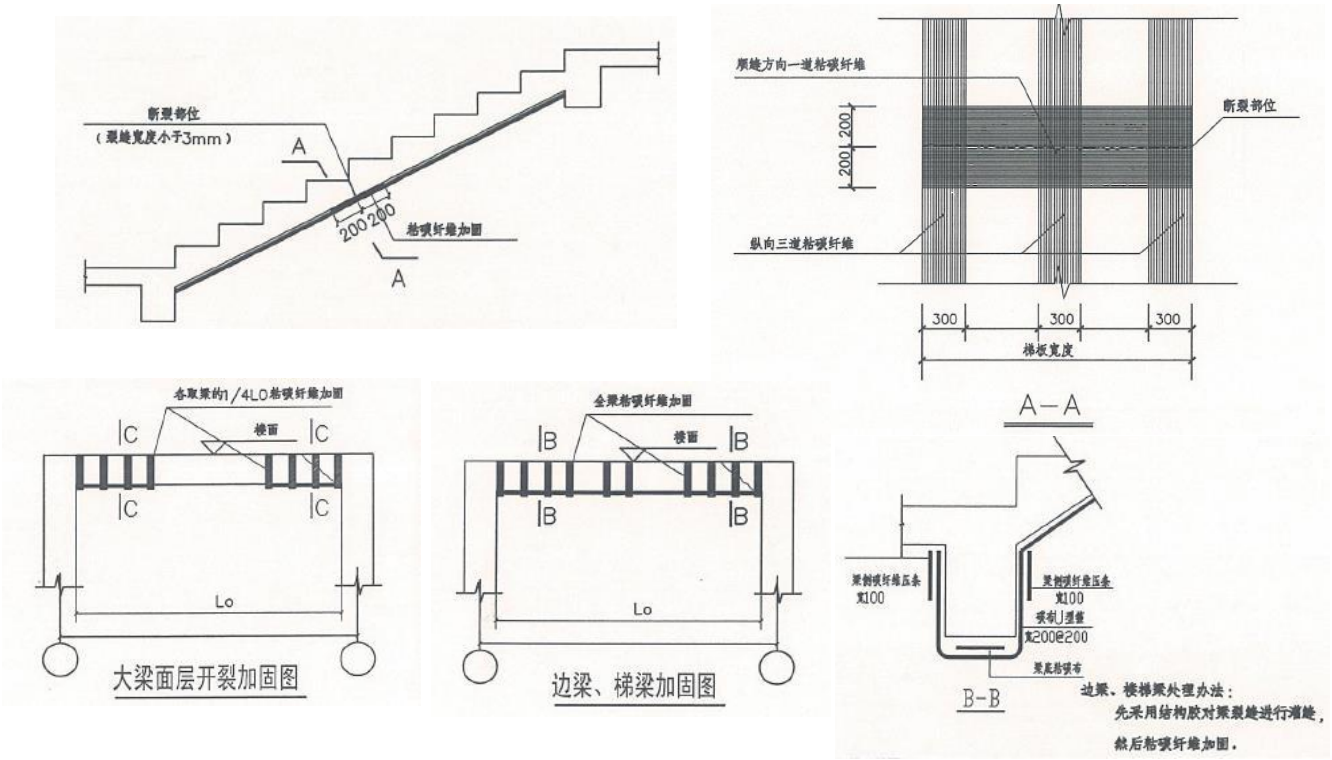
- Bracing with suitable materials such as Fibre reinforced Polymer (FRP), canvas or wire mesh can mitigate the abrupt collapse of a brick wall by restraining the bricks from being dislodged in the event of mortar failure.



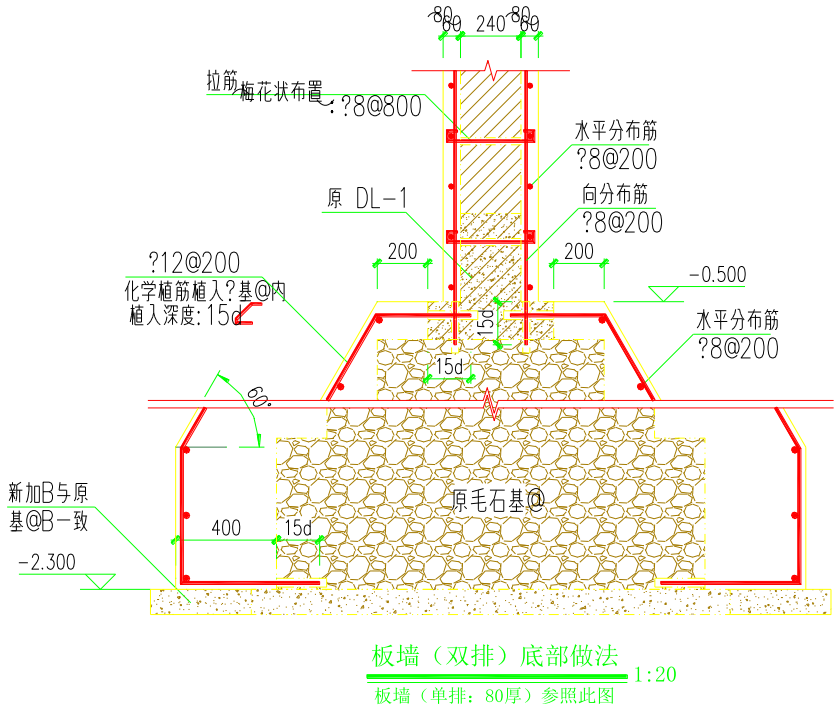
Repairing cracks in walls using criss-cross FRP bracing along the cracks

(iii) Strengthening of evacuation routes

- Strengthening of staircases and openings by strategically placed reinforcement above and below openings, along with vertical reinforcement adjacent to vertical edges.



Strengthening of evacuation points - staircase



Strengthened walls have been securely anchored with steel mesh and tie bars to the foundation

Projects - seismic strengthening in school buildings in China

- NTU has undertaken a program for improving seismic safety of buildings in China.
- Program objective is training and demonstration of proper construction technologies for earthquake resistance.
- NTU will train faculty members, researchers and graduate students as '*Master Trainers*'.
- Seismic strengthening technologies developed by NTU will be implemented by local builders, who will apply these methods in 12 schools in China.