M Tower Structural Concept

Place Novotel Hotel, Yangon
Date 2018.10.30

Calvin Chang

BSc (civil) · MSc (structural)
registered structural engineer (Taipei)
apec engineer · IntPE

Mottama
Holdings Ltd.

Calvin Consulting Engineers
Pacific Seismic Professionals Taiwan

Myanmar · Taipei

Basic Structural Idea

Material Selection

Steel building vs RC building

Seismic

Wind

Construction method

Construction duration

……

Seismic Damage of RC Buildings


What is Earthquake ?

Give me 1 Minute

I can destroy your everything

Calvin Chang 1999-2018

about 240,000 Died

1976

Died
240,000

1995

20 second

Died
4,569

Buildings
Collapsed
or Damaged
190,000

RC building collapse – 115 Died • Tainan

2016

Died
117

維冠金龍大樓倒塌 – 115 人死亡 • 台南

I am Calvin from Taiwan

BSc, Civil Engineering, National Chiao-Tung University

MSc, Civil Engineering (Structural), National Taiwan University

registered structural engineer & seismic design (Taiwan 20+ year)

apec engineer

IntPE

CPEng (Australia)

Calvin Consulting Engineers, Taiwan & Myanmar

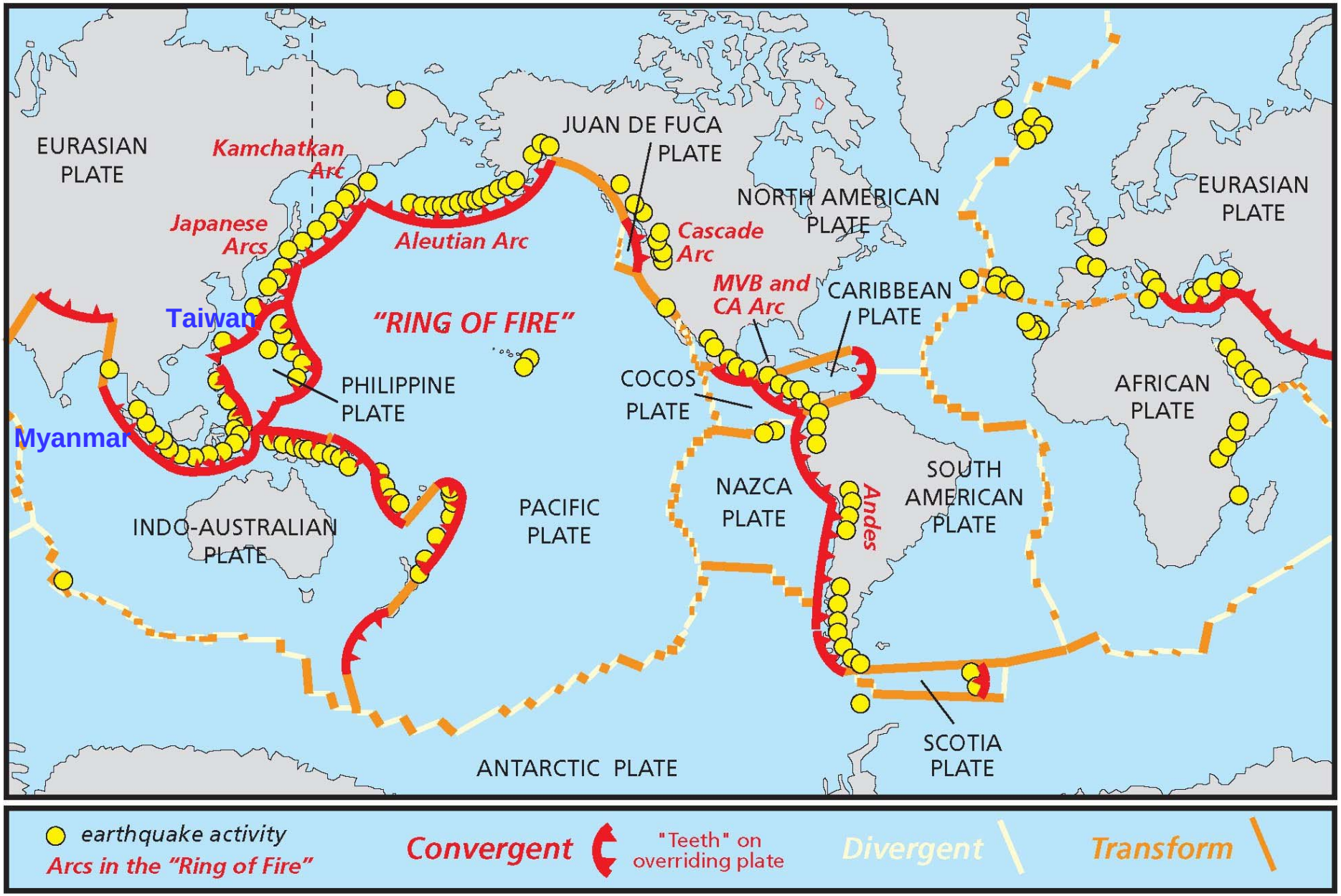
Natural Risk Hazards Atlas • 2014

Rank	Country	Category
1	Japan	Extreme
2	USA	Extreme
3	Taiwan	Extreme
4	China	Extreme
5	India	Extreme

Rank	Country	Category
6	Mexico	High
7	Philippines	High
8	Italy	High
9	Australia	High
10	Indonesia	Medium

Legend
Extreme
High
Medium
Low
No data

Pacific Ring of Fire

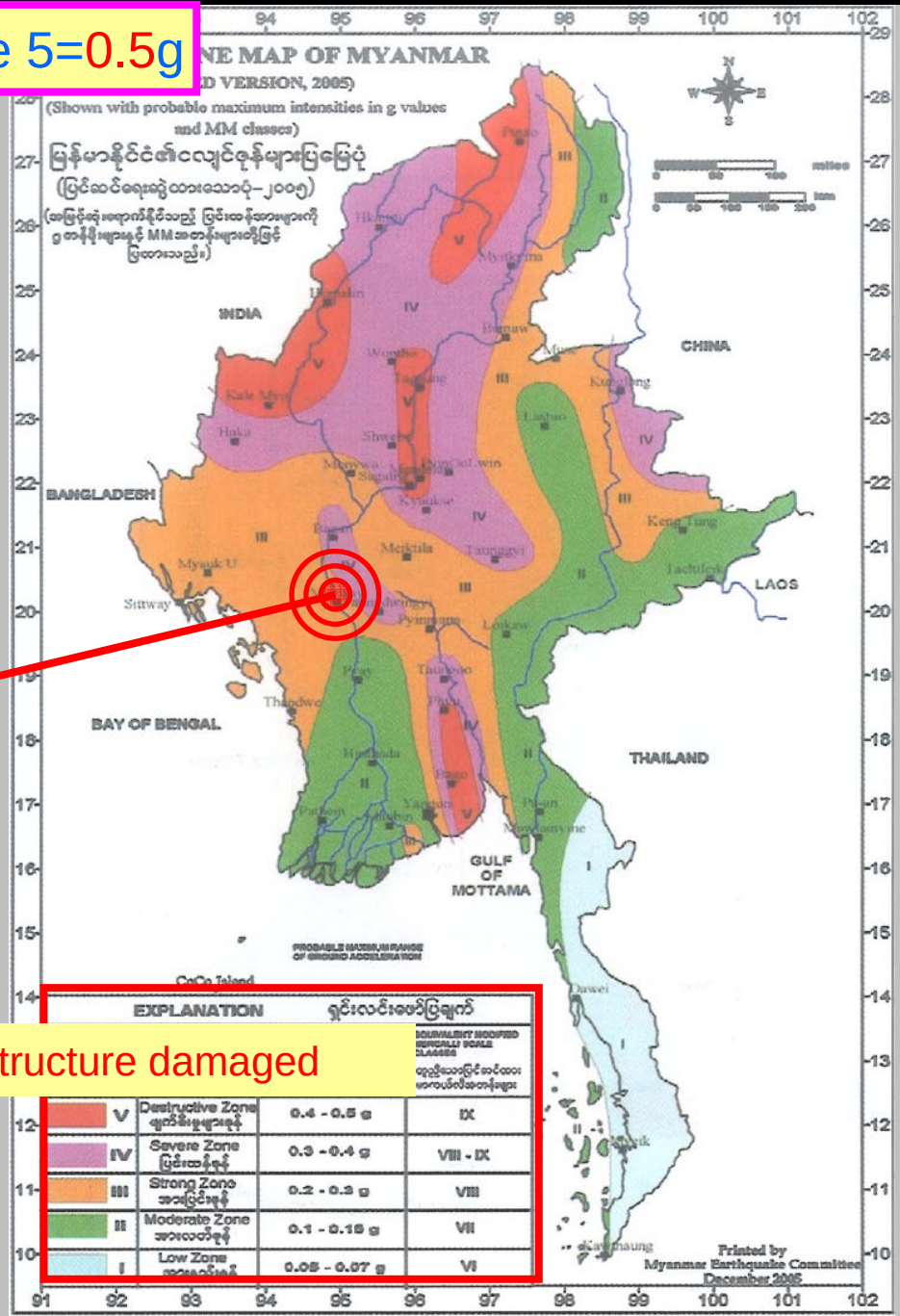


Myanmar Seismic Zoning Map

Zone 1=0.1g ~ zone 5=0.5g

2016

Died
4



M 6.8

earthquake

25 km west of

4 people died • ancient structure damaged

2016/08/24

Chi-Chi Earthquake 1999 Taiwan

19 years ago

Calvin 1999

Why building collapsed ?

Why building NOT collapsed ?

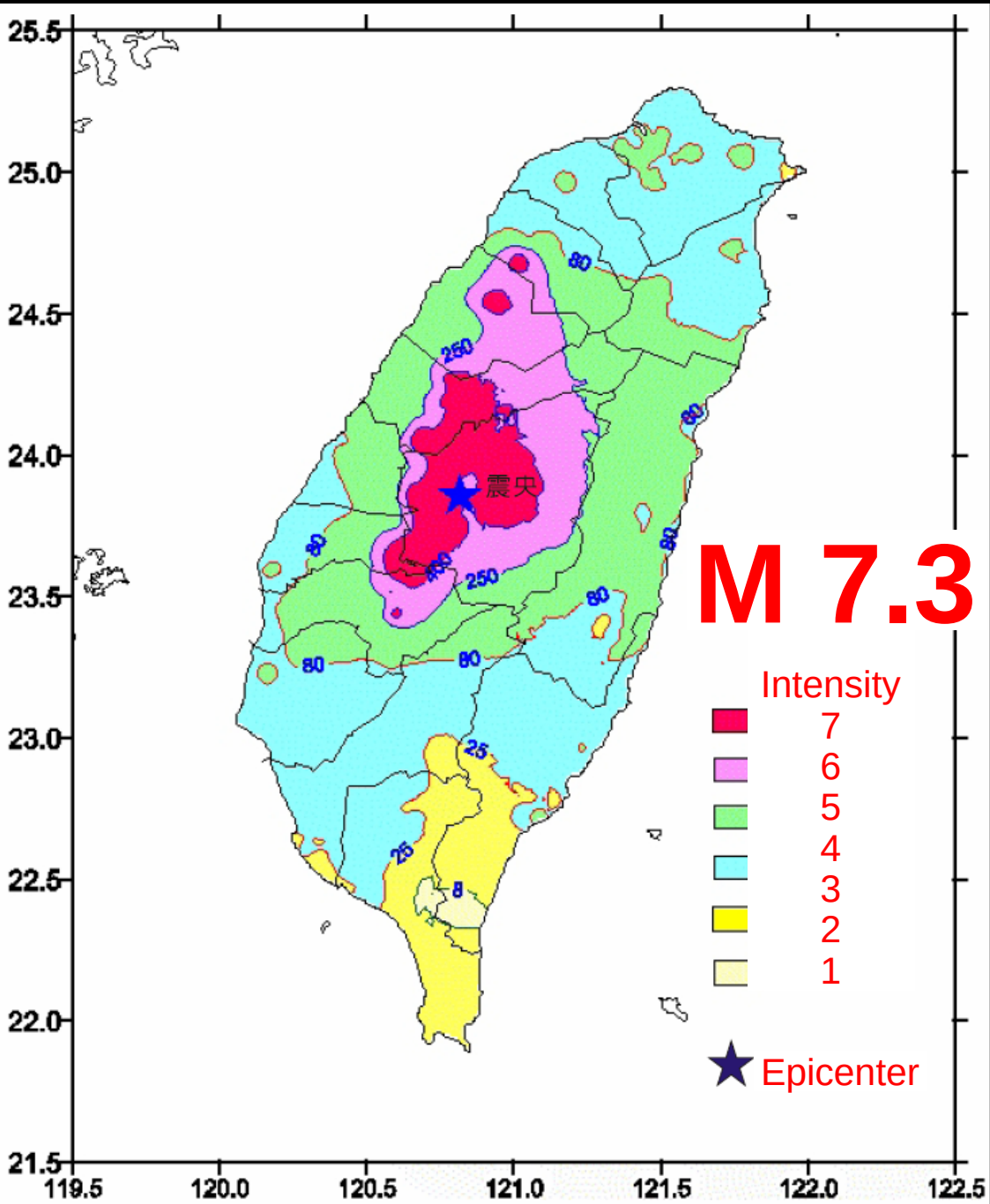
Calvin 1999-2018

Why Collapse?

Why Survive?

Are we ready
for our next move?

Calvin 2018



Died 2,415

Injured 11,305

Buildings Collapsed

51,711 totally

53,768 partially

Building Collapse partially
4 Died
Taichung

4 Died

德昌新世界倒塌
4 人死亡
台中

Building Collapse Partially – 4 Died • Taichung

4 Died

德昌新世界倒塌 – 4 人死亡 • 台中

Building Collapse – 4 Died • Taichung

德昌新世界倒塌 – 4 人死亡 • 台中

Building Collapse – 9 Died • Yunlin

9 Died

16 Stories - Only 9 Stories Left

斗六觀邸倒塌 – 9 人死亡 • 雲林

Building Collapse – 14 Died • Taichung

14 Died

Soft First Story Pancake &
Cantilever Balcony Collapse

豐原市聯合市場倒塌 – 14 人死亡 • 台中

Building Collapse – 28 Died • Taichung

28 Died

東勢王朝倒塌 – 28 人死亡 • 台中

Building Collapse – 29 Died • Taichung

29 Died

台中王朝倒塌 – 29 人死亡 • 台中

Building Collapse – 32 Died • Taichung

32 Died

豐原市向陽路大樓倒塌 – 32 人死亡 • 台中

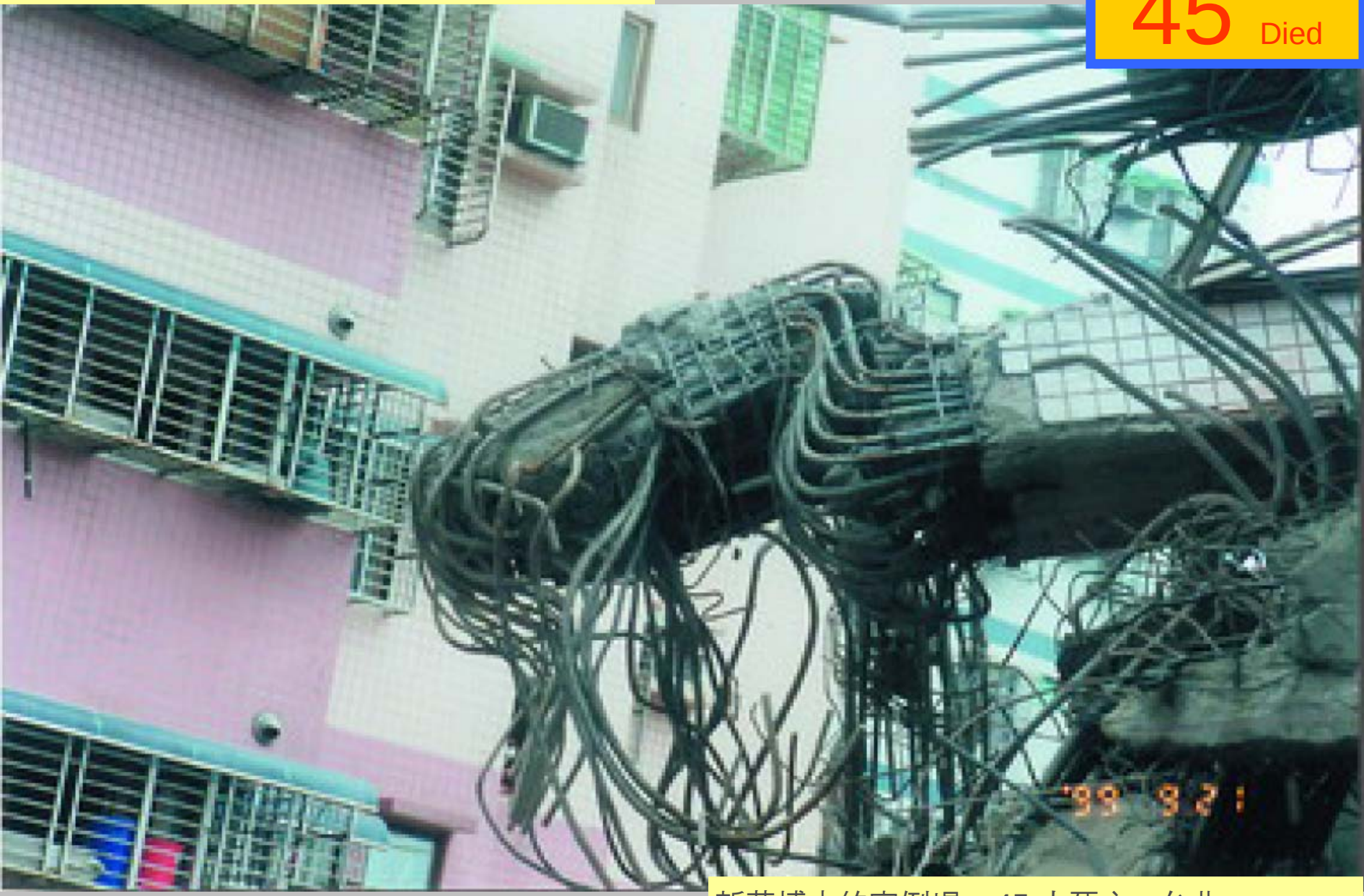
Building Collapse – 45 Died • Taipei

45 Died

新莊博士的家倒塌 – 45 人死亡 • 台北

Building Collapse – 45 Died • Taipei

45 Died



新莊博士的家倒塌 – 45 人死亡 • 台北

Building Collapse – 80 Died • Taichung

80 Died

大里金巴黎倒塌 – 80 人死亡 • 台中

Building Collapse – 80 Died • Taichung

80 Died

大里金巴黎倒塌 – 80 人死亡 • 台中

Building Collapse – 80 Died • Taichung

80 Died

大里金巴黎倒塌 – 80 人死亡 • 台中

Building Collapse – 80 Died • Taichung

80 Died

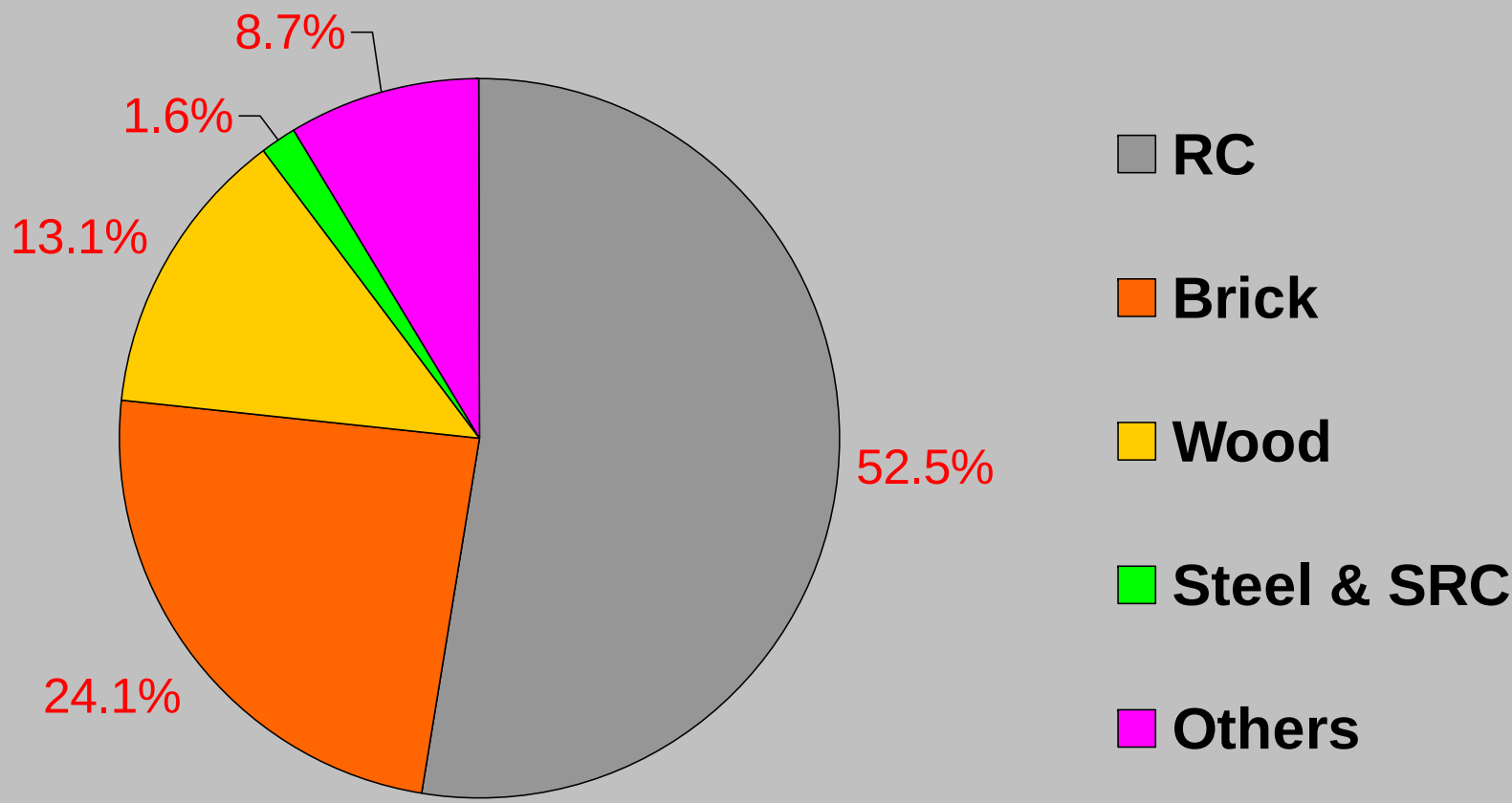
大里金巴黎倒塌 – 80 人死亡 • 台中

Dong Xing building collapse – 87 Died • Taipei

87 Died

東興大樓倒塌 – 87 人死亡 • 台北

Damaged/ Collapsed Buildings Summary of 921 Earthquake 1999



Conclusion

No matter how we learned from the past,

how technology & code developed,

.....

It’s difficult to catch the future earthquake.

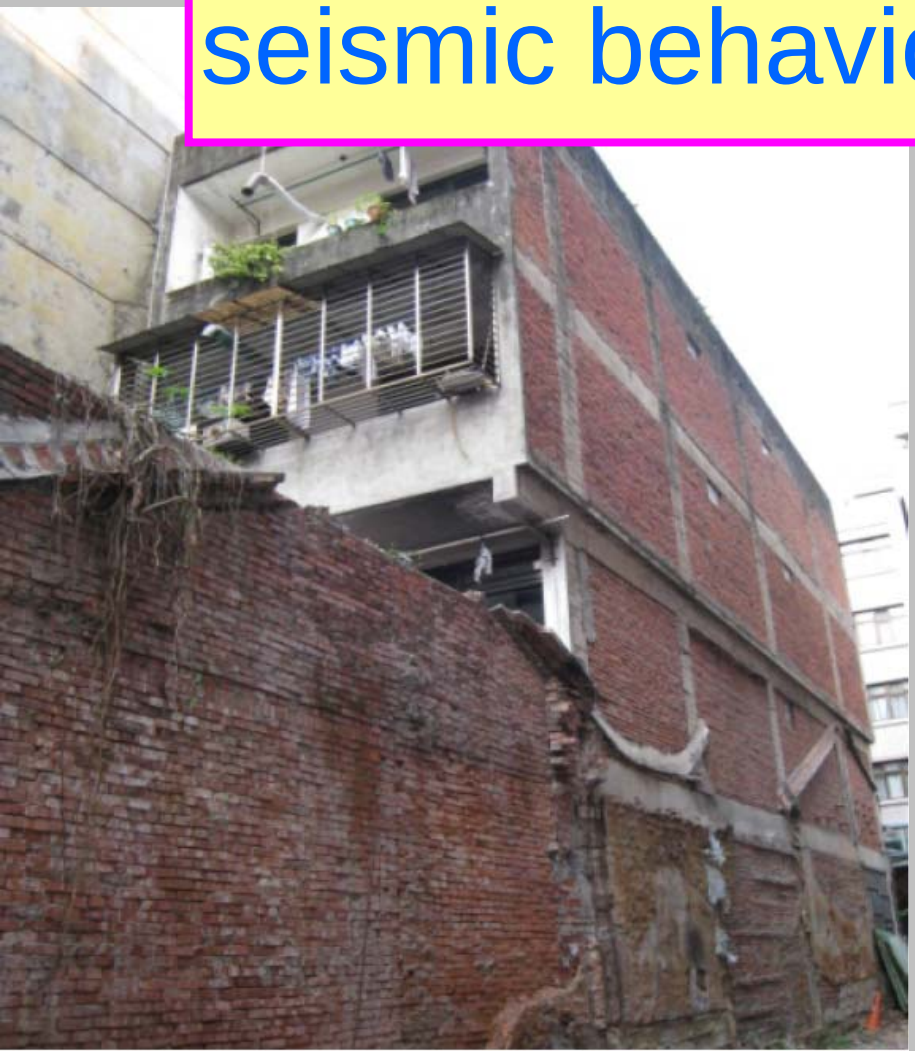
Similar damage / mistakes repeats over & over again.

Wall Problems

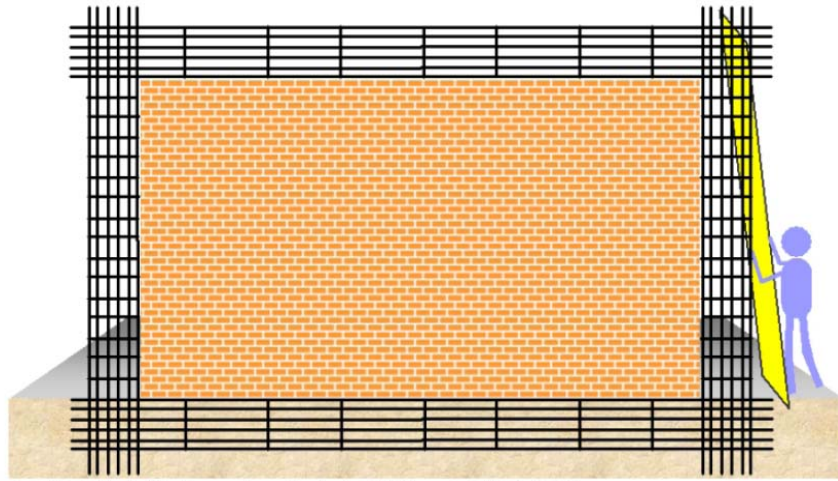
RC buildings

Non-Structural Wall might Kill a Building.

The Wall (RC/ Brick/ Masonry) totally change the building seismic behavior



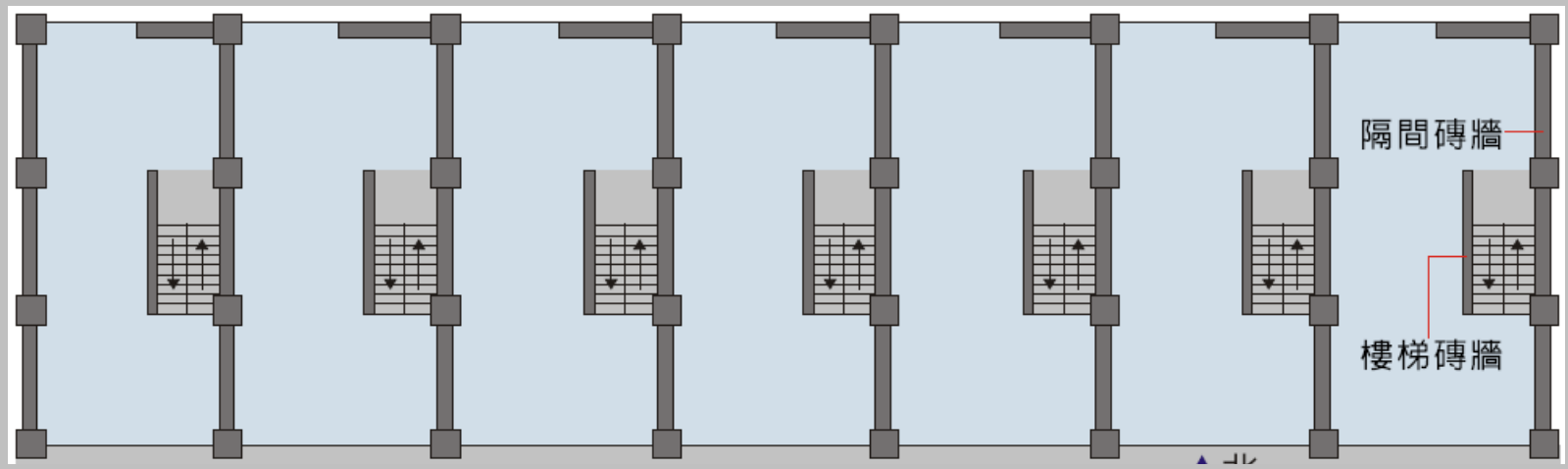
Stiffness Un-uniform
&
Force Concentration



加強磚造建築施工時，先砌好磚牆，再搭建梁柱

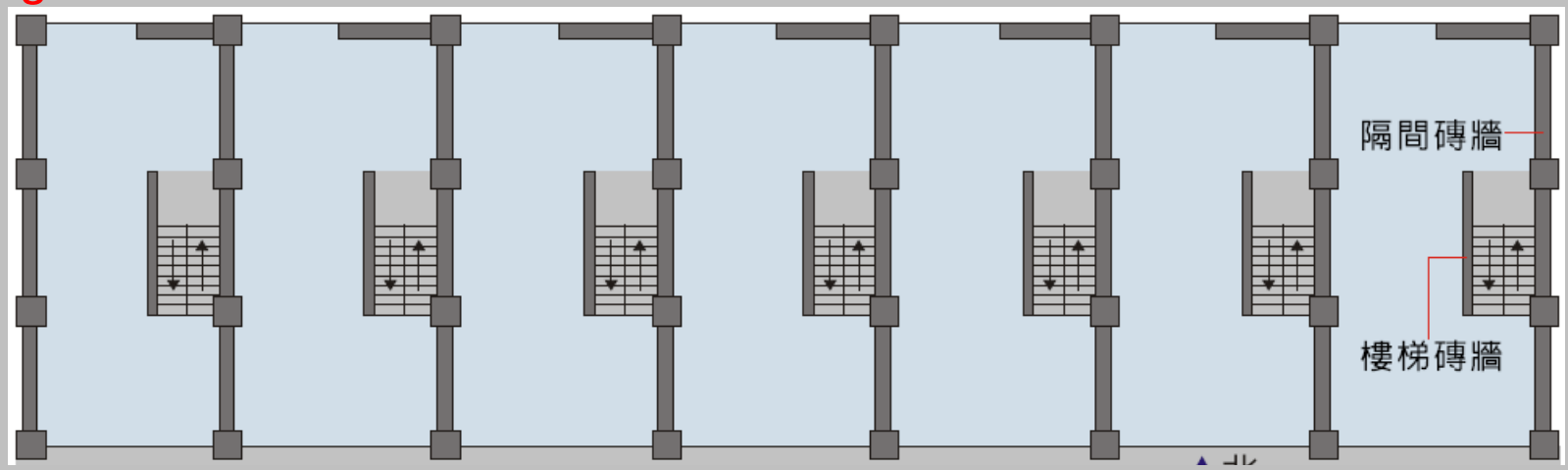
Which Direction (Short or Long) is Stronger ?

Short Direction Weak



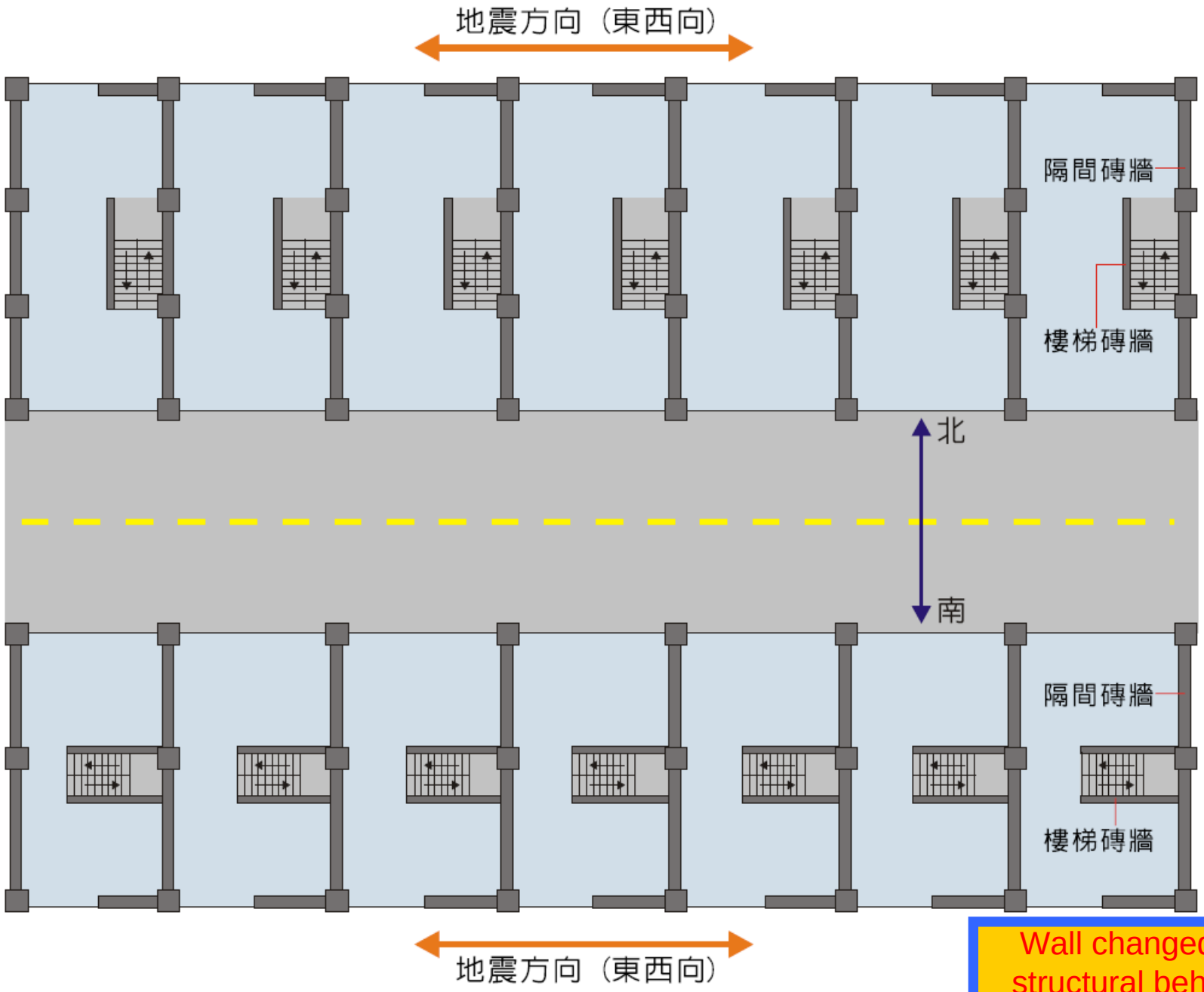
Long Direction Strong

Short Direction Strong



Long Direction Weak

Wall changed the structural behavior



Wall changed the structural behavior

Soft First Story • Taichung

大全街騎樓住宅 • 台中

Soft First Story • Taichung

大全街騎樓住宅餘震倒塌 • 台中

Soft First Story Collapse • Taichung

台中客運倒塌 • 台中

Soft First Story • Taichung

大坑軍功路 • 台中

Soft First Story • Taichung

大坑軍功路 • 台中

Soft First Story Pancake • Taichung

東勢農會大樓一樓壓跨 • 台中

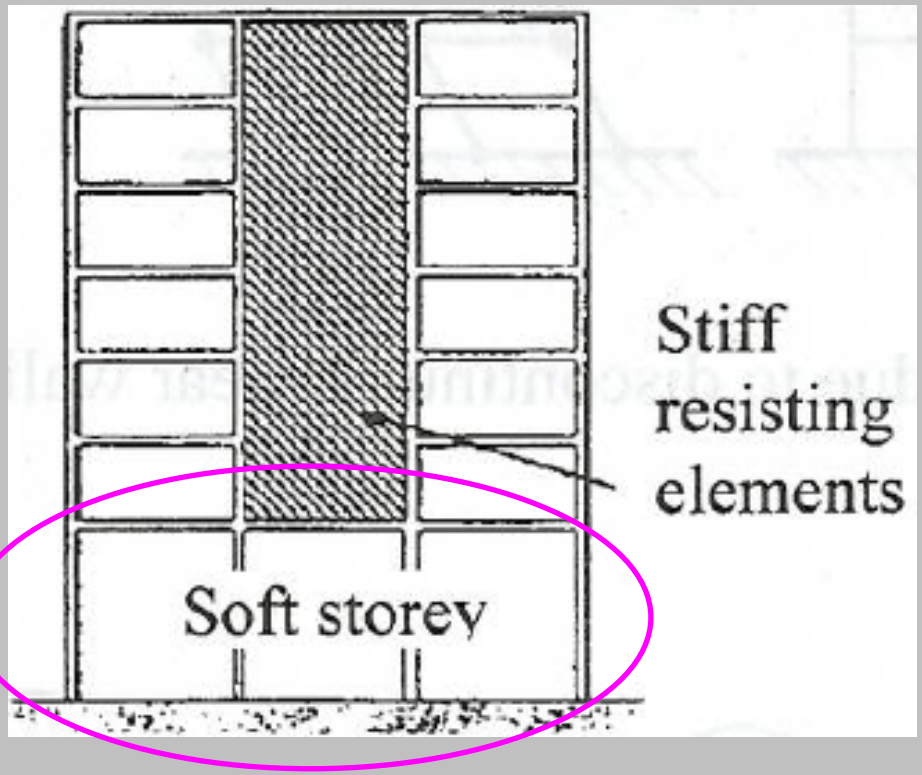
Soft First Story • Taichung

台灣省中等學校教師研習會 • 豐原

Soft First Story • Taichung

台灣省中等學校教師研習會 • 豐原

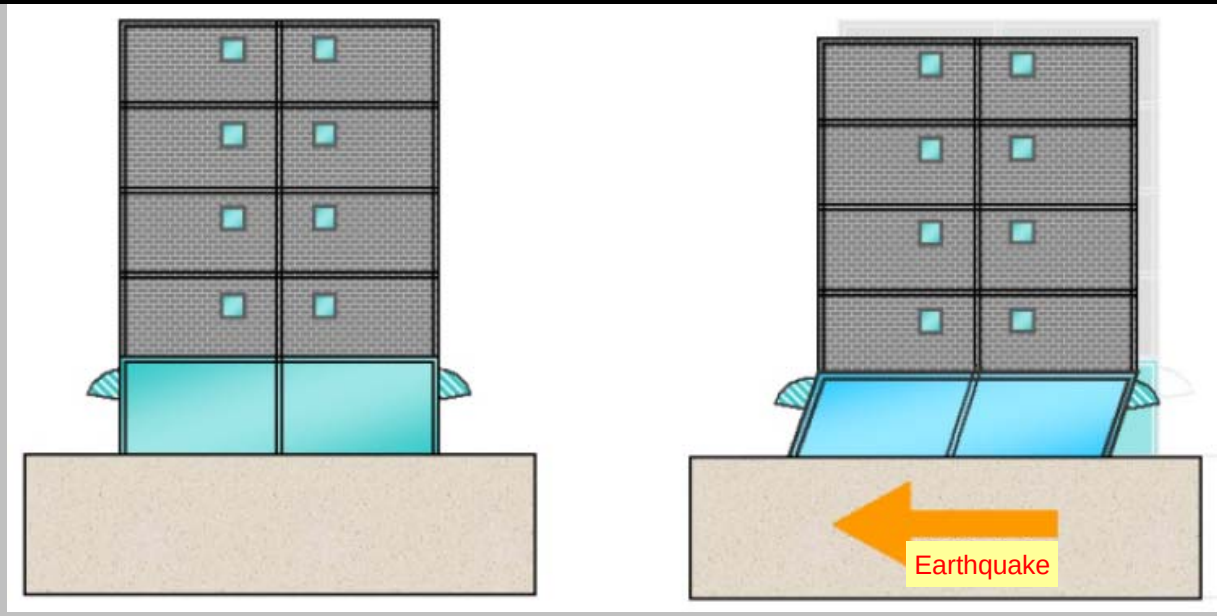
Vertical Irregularity Check



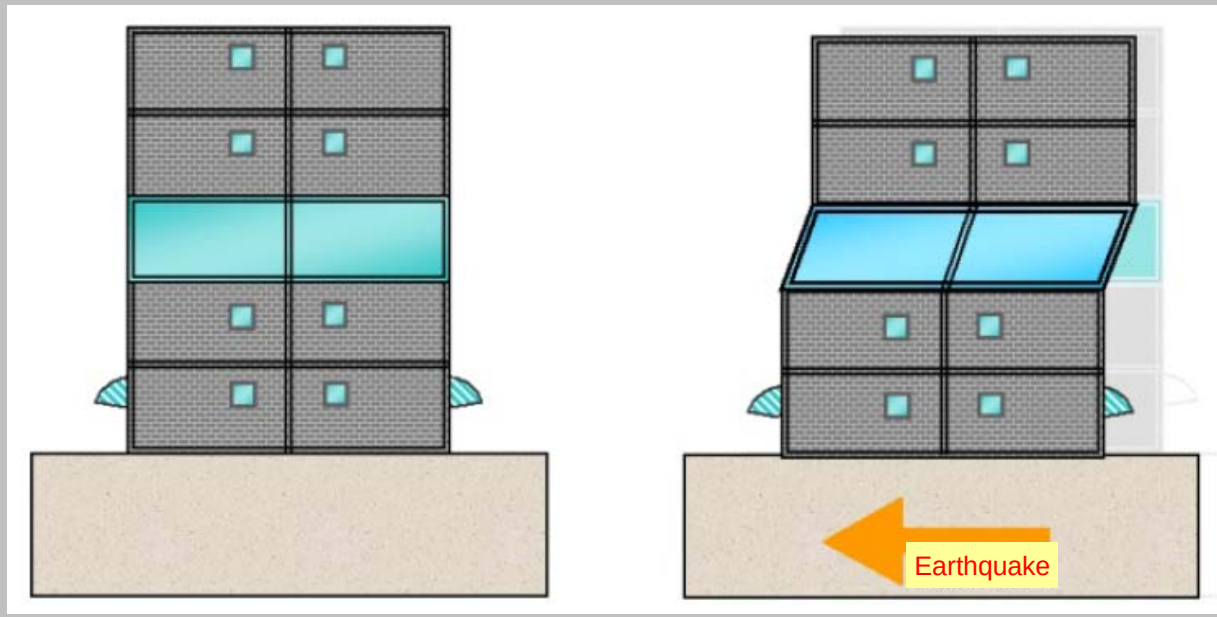
story stiffness below
＞70% story stiffness above
＞80% average stiffness of 3 stories above

Wall Quantity Not Enough

Soft First Story



Soft Medium Story



Wall Quantity Not Enough

Soft First Story Pancake

Soft First Story Severely Damaged

Column Shear Failure

Short Column - Shear Failure

YCDC HIC Building

YCDC HIC Building

YCDC HIC Building

Watch again

Which is Strong ?
Column or Girder ?


aksa

Wall Problem

Not only the **Weight** problem

It's **Stiffness** problem.

Walls totally change the structural behavior.

Not easy to predict the seismic behavior.

Non-Structural Wall might **kill a Building**.

Need to carefully arrange the non-structural wall.

For M Tower
Pure Steel Frame + Curtain wall + Dry wall
➔ No Wall Problem

Advantage of Steel Buildings

Light Weight

Curtain Wall (exterior) flexible

Dry Wall (interior) flexible

Standard Practice for Steel Building

Keep the main frame uniform & regular, not affected by the wall as the RC buildings.

Good seismic performance.

……

LEED

Regular Structural System

Light Weight Structure

Dry Wall Partitions

Curtain Wall

Material Recycled

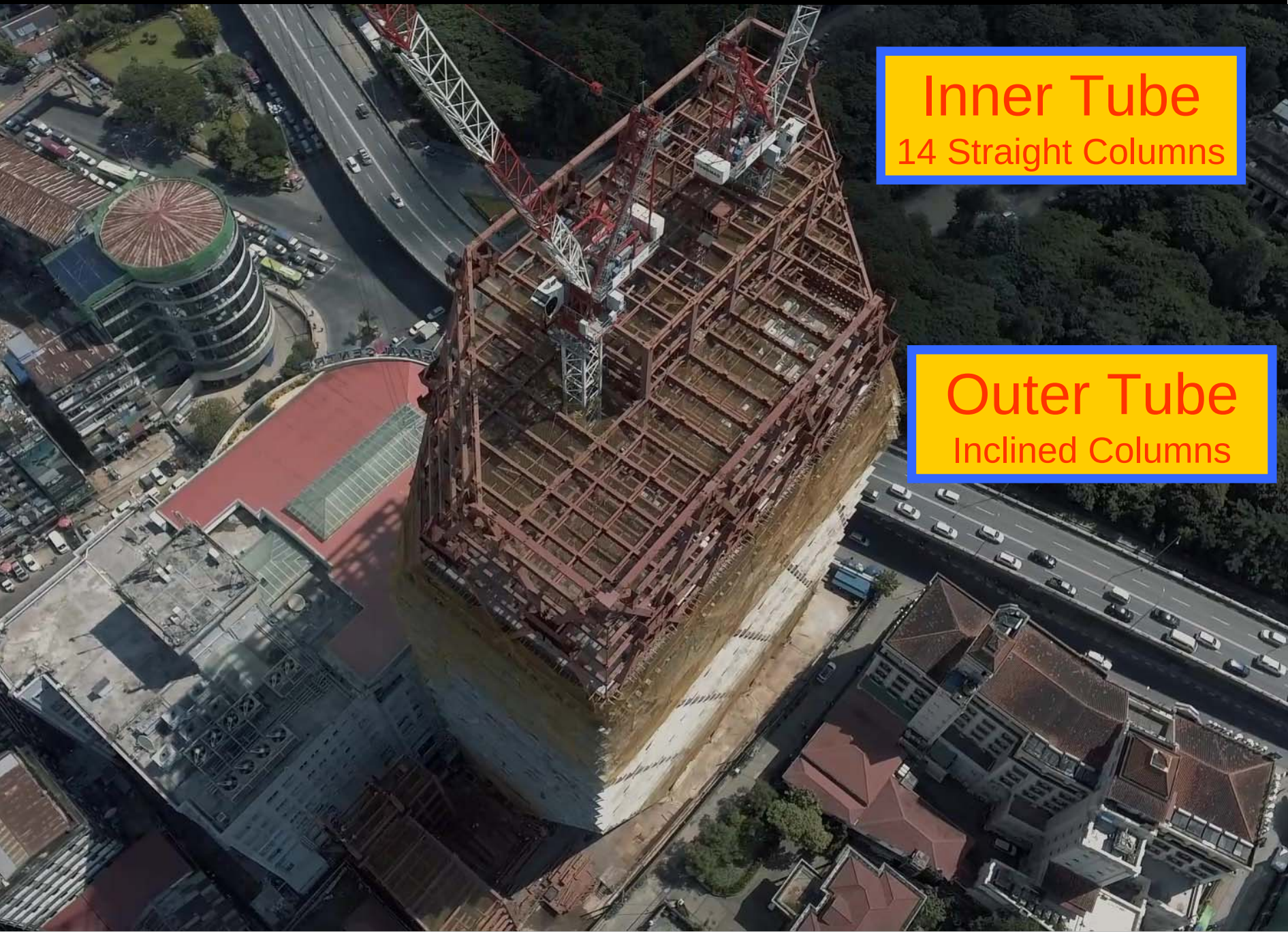
Sustainable

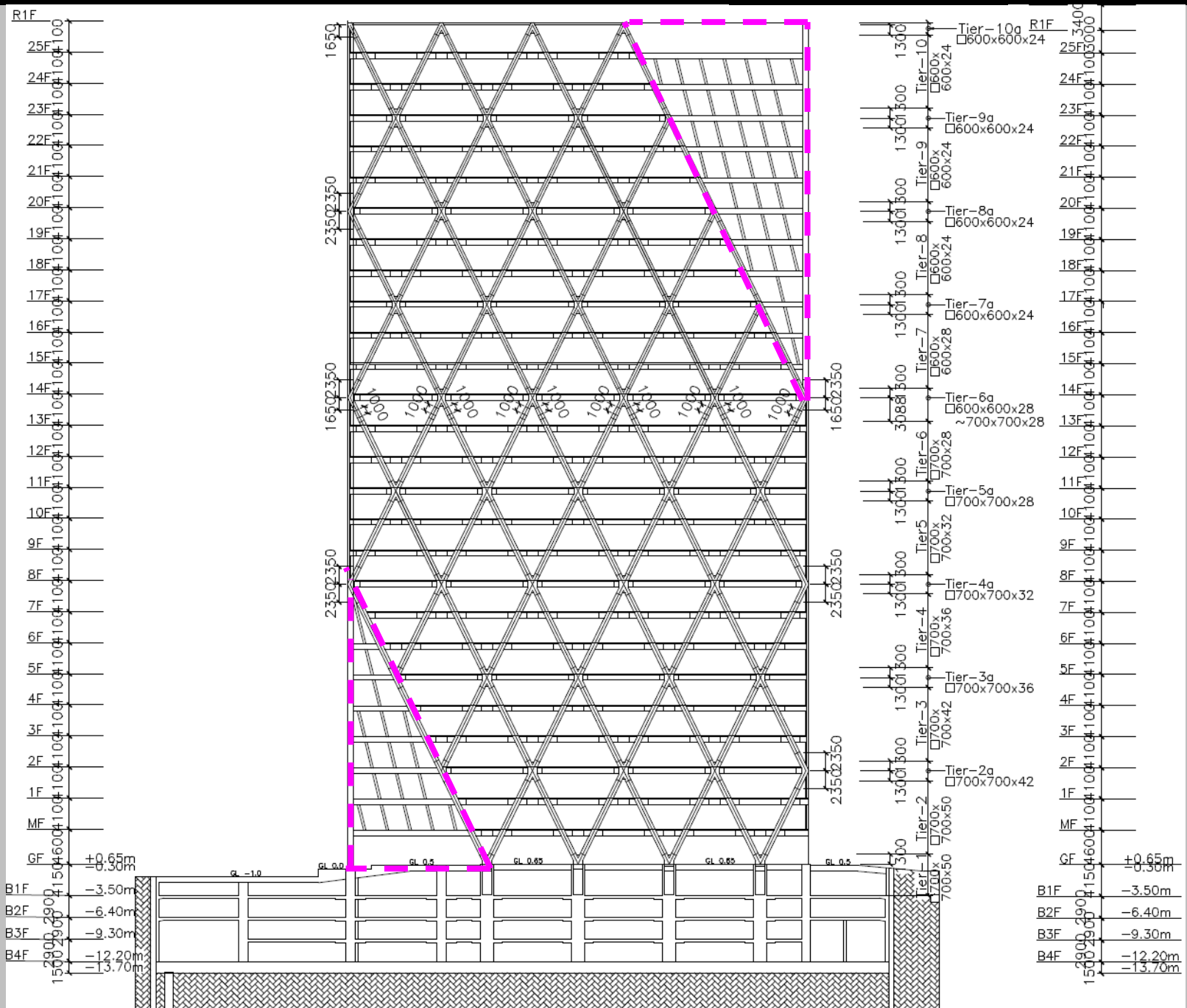
Steel is compatible with the LEED

M Tower Structural System

Tube in Tube system (Inner Tube + Outer Tube)

Basement RC + Superstructure Steel


Inner Tube
14 Straight Columns
Outer Tube
Inclined Columns


R1F
25F
24F
23F
22F
21F
20F
19F
18F
17F
16F
15F
14F
13F
12F
11F
10F
9F
8F
7F
6F
5F
4F
3F
2F
1F
MF
GF +0.65m -0.30m
B1F -3.50m
B2F -6.40m
B3F -9.30m
B4F -12.20m -13.70m
Tier-10a □600x600x24
Tier-9a □600x600x24
Tier-8a □600x600x24
Tier-7a □600x600x24
Tier-6a □600x600x28 ~700x700x28
Tier-5a □700x700x28
Tier-4a □700x700x32
Tier-3a □700x700x36
Tier-2a □700x700x42
GL -1.0
GL 0.0
GL 0.5
GL 0.65
GL 0.85
GL 0.5

Curtain Wall

Curtain Wall System

Stick System

Unitized System

Glass Wall System

…, etc.

Like a Curtain (Flexible) (The curtain moves with wind)

Aluminum Frame + Panel or glass

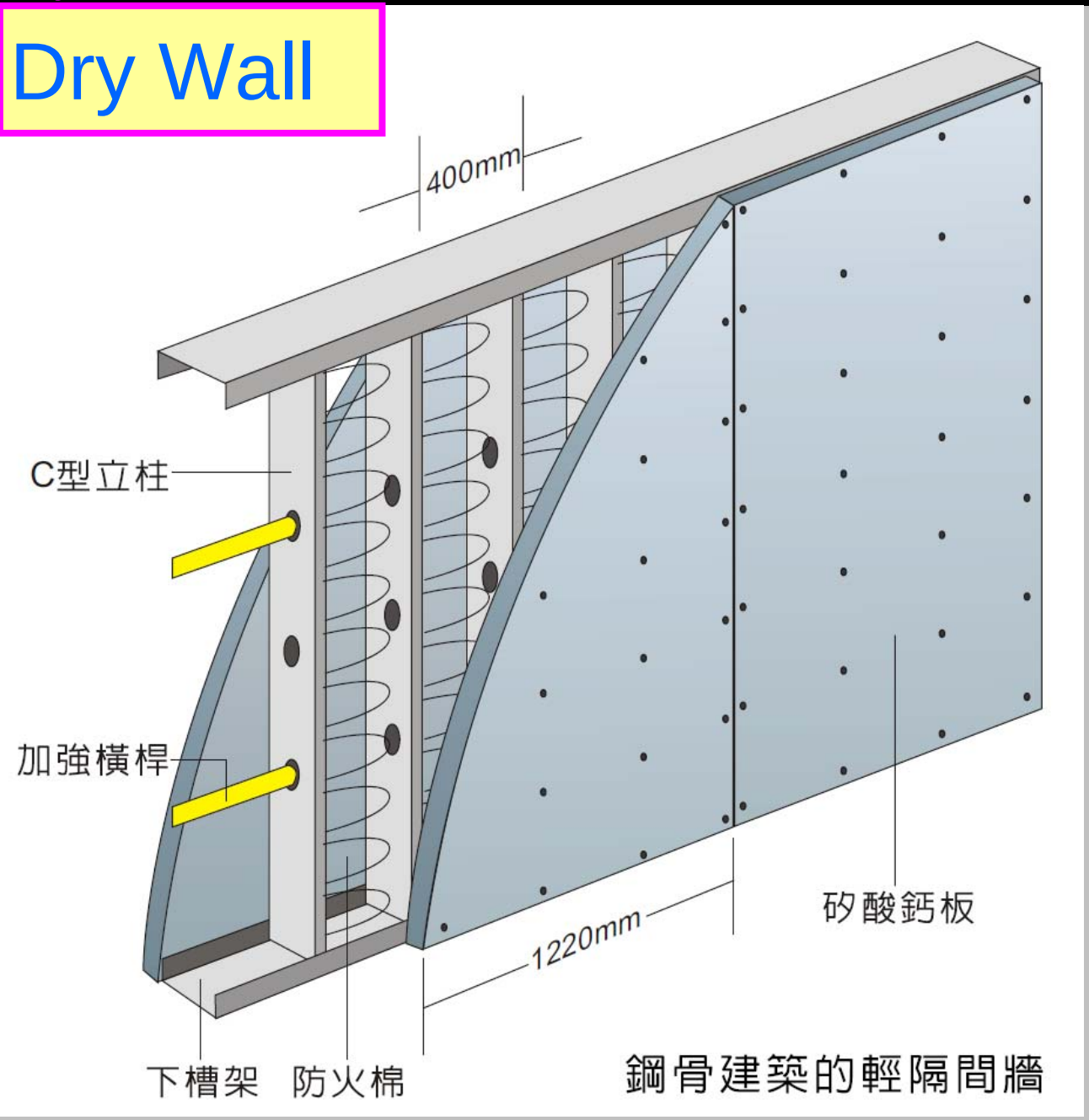
Light Weight (<100 kg/m^2) vs. RC wall (400 kg/m^2)

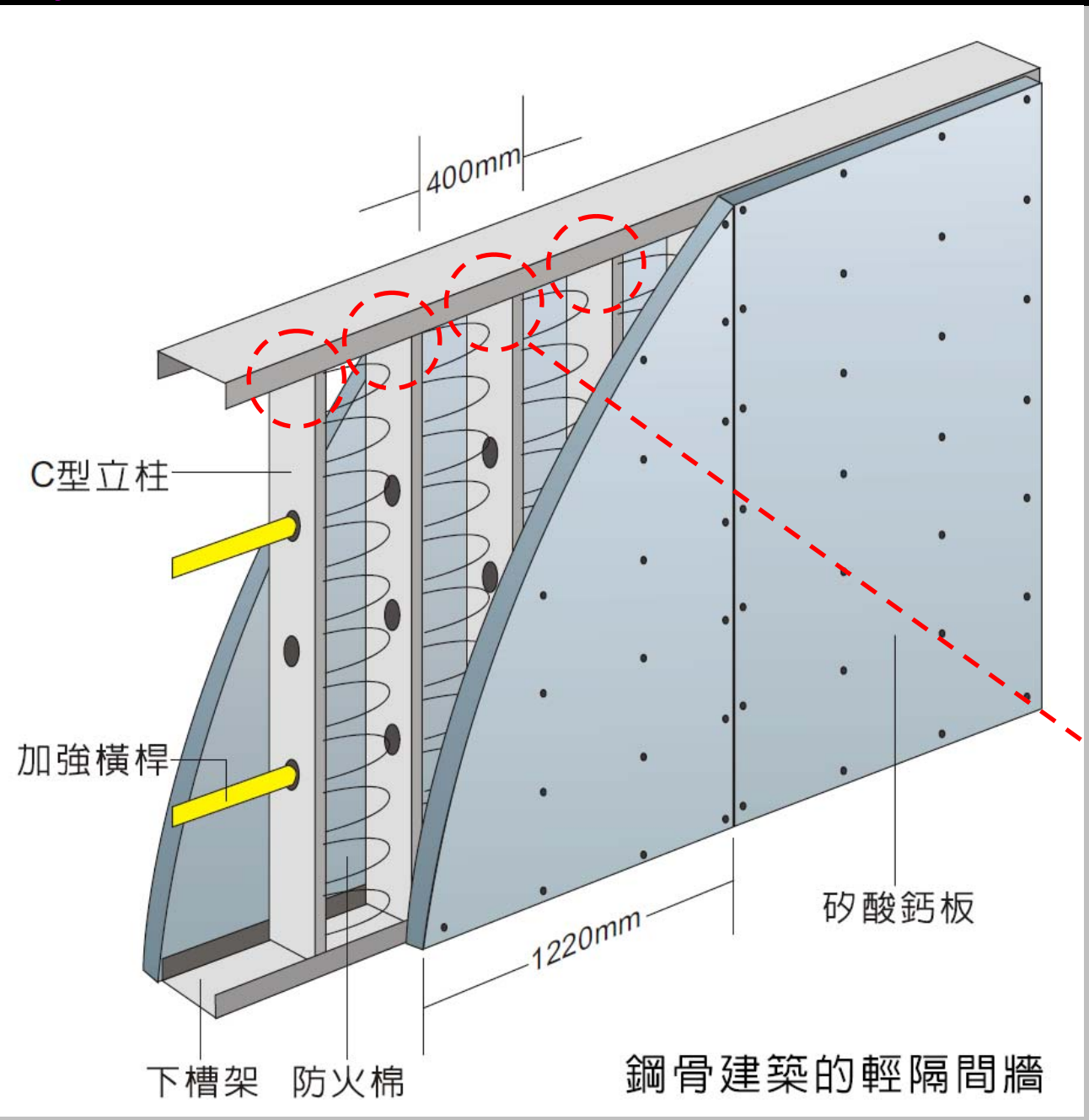
Cover outside of the main frame.

Do not affect the main frame behavior.

Dry Wall

Dry Wall

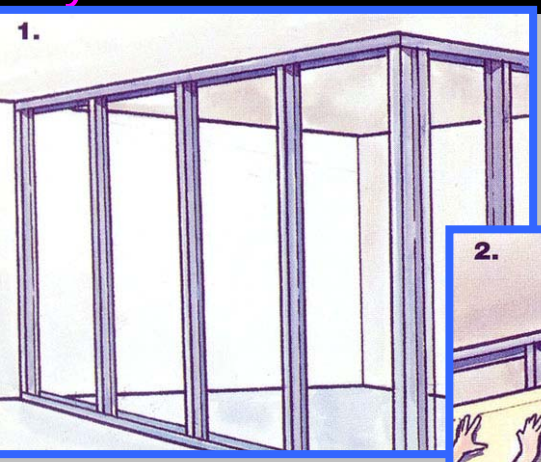




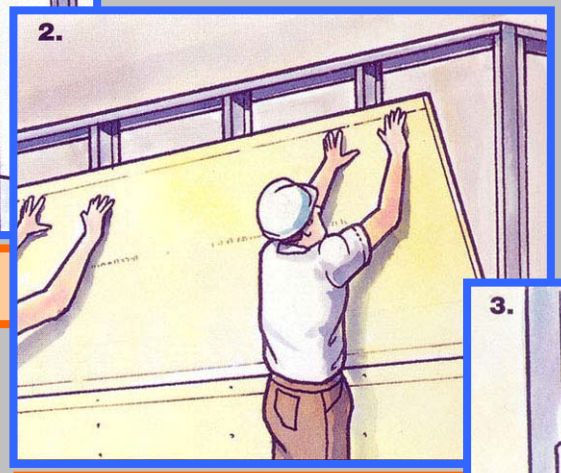
Top of stud

10 mm gap

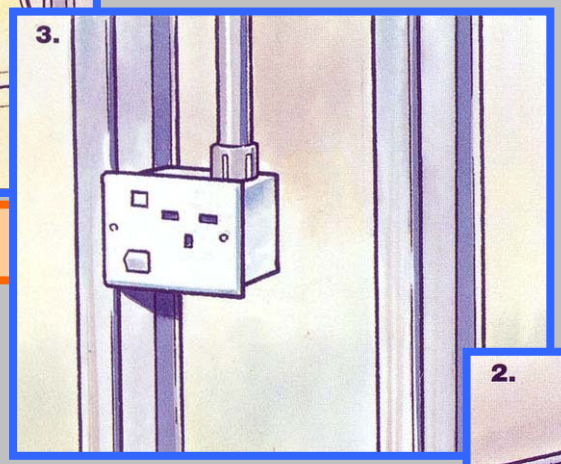
Flexible with the main frame



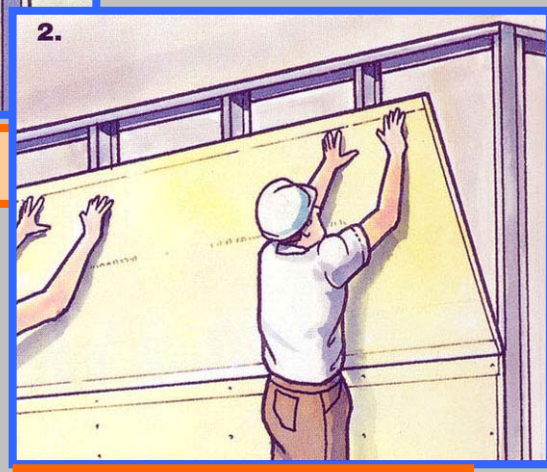
1. Light frame



2. 1st side board



3. M&E Plumbing



4. 2nd side board


2003 5 31

Dry Wall

Diagrid Structure

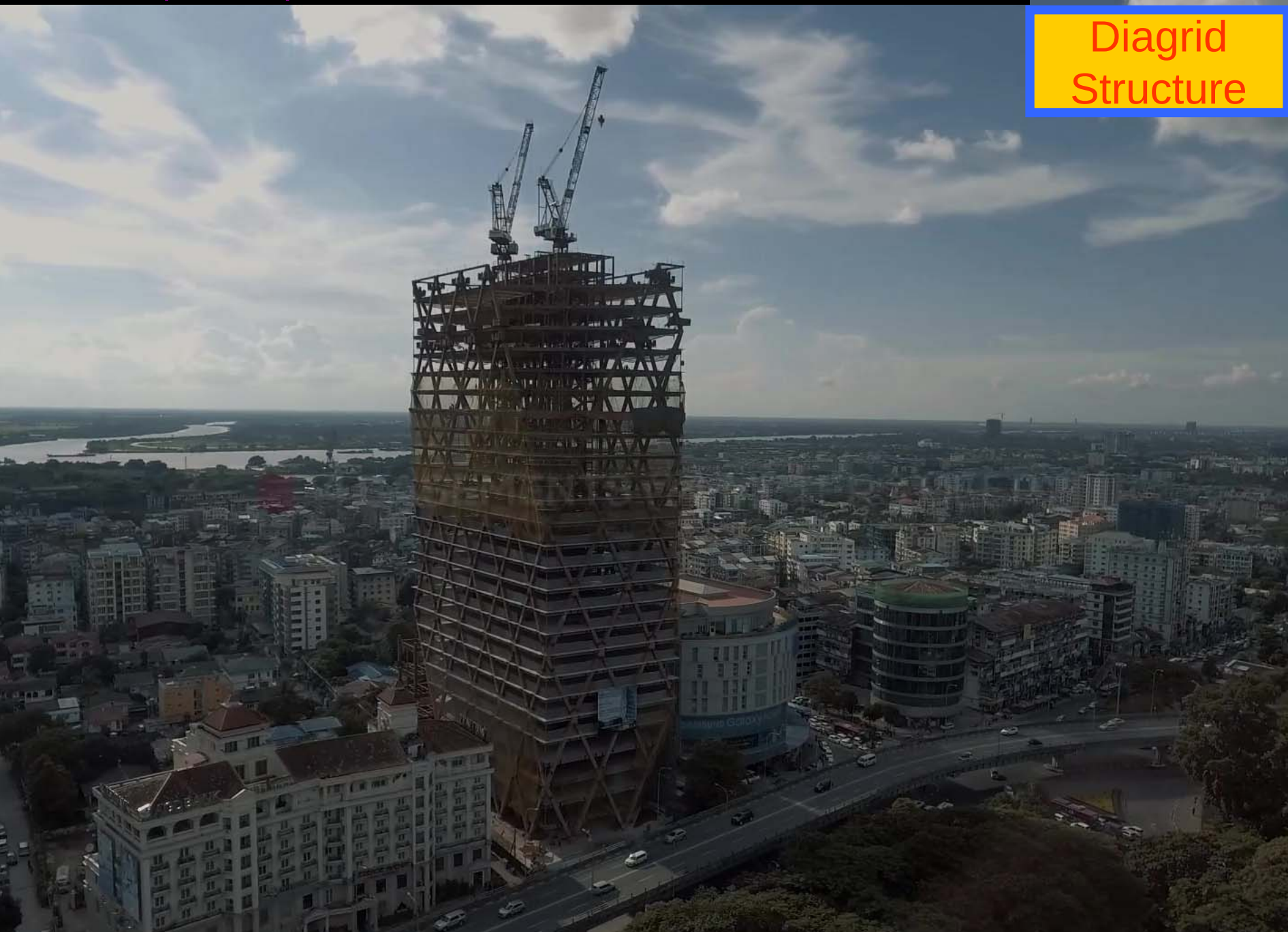
Challenging

Unique & Special

X . Y . y . v . K . . . joints

Diagrid Structure

a+pgrp


Diagrid
Structure

X Joint

Y Joint

y Joint

K Joint

Box column vs H column

Box Column: No weak axis

H Column: Strong axis & weak axis

For M Tower, all main columns are box columns

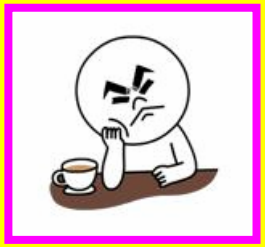
Question

27 storey building, column area 60m^2, story height = 5m, P=1800 ton

H 400x400x13x21
(A572 G50)

w=	172 kg/m
A=	219 cm^2
r_x=	17.4 cm
r_y=	10.1 cm
L=	500 cm
L/r=	49
f_a=	1.72kgf/cm^2
$P_a=f_aA$=	**380** ton
<	1800 ton

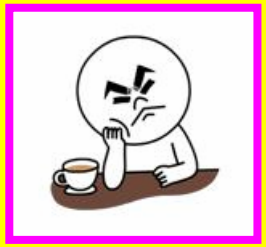
NG



H 458x417x30x50
(A572 G50)

w=	415 kg/m
A=	529 cm^2
r_x=	18.8 cm
r_y=	10.7 cm
L=	500 cm
L/r=	47
f_a=	1.74kgf/cm^2
$P_a=f_aA$=	**920** ton
<	1800 ton

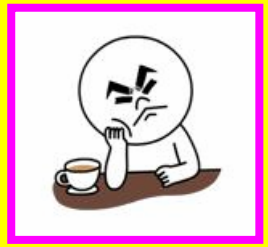
NG



H 498x432x45x70
(A572 G50)

w=	605 kg/m
A=	770 cm^2
r_x=	19.7 cm
r_y=	11.1 cm
L=	500 cm
L/r=	45
f_a=	1.77kgf/cm^2
$P_a=f_aA$=	**1360** ton
<	1800 ton

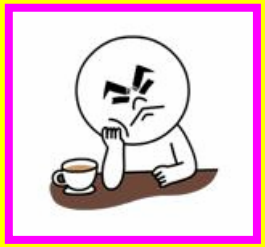
NG



388x402x15x15
394x398x11x18
394x405x18x18
400x400x13x21
400x408x21x21
414x405x18x28
428x407x20x35
458x417x30x50
498x432x45x70

Nothing to choose

NG



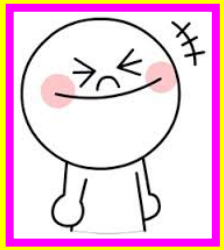
Question

27 storey building, column area 60m^2, story height = 5m, P=1800 ton

□ 700x700x50x50
(A572 G50)

w=	1020 kg/m
A=	1300 cm^2
r_x=	26.6 cm
r_y=	26.6 cm
L=	500 cm
L/r=	19
f_a=	2.0kgf/cm^2
$P_a=f_aA$=	**2600** ton
>	1800 ton

OK



□ 1500x1500x50x50
(A572 G50)

w=	2277 kg/m
A=	2900 cm^2
r_x=	59.2 cm
r_y=	59.2 cm
L=	500 cm
L/r=	9
f_a=	2.06kgf/cm^2
$P_a=f_aA$=	**6000** ton
>	1800 ton

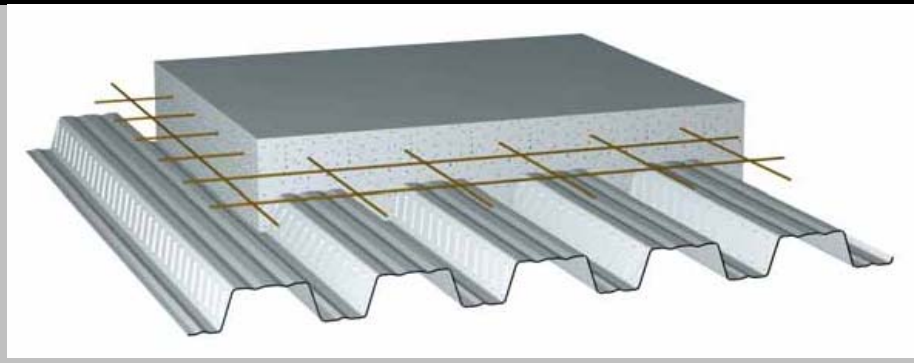
OK

Min Dhama
Steel Structures Co., Ltd.
Maximum Size Today

Floor System

130 mm composite slab

NCCI: Fire resistance design of composite slabs



The UK National Annex to BS EN 1994-1-2 recommends that informative Annex D should not be used. This NCCI document provides alternative guidance.

Concrete type	Minimum thickness of concrete for a fire resistance period of:			
	I30	I60	I90	I120
NC	100	100	110	125
LC	100	100	105	115

use 130 mm

For S1 slab, overall thickness＝130㎜＞125㎜, OK

For S2 slab, overall thickness＝150㎜＞125㎜, OK

For S3 slab, overall thickness＝200㎜＞125㎜, OK

2 Hour

No shoring is required

No shoring is required

Foundation

Pile foundation (D1.0m & D1.2m)


SGW

Excavation

Diaphragm Wall 0.7m

Traditional bottom up construction

Transfer Story

Basement: RC

Superstructure: Steel

Where to change?

RC column ➔ Steel Column

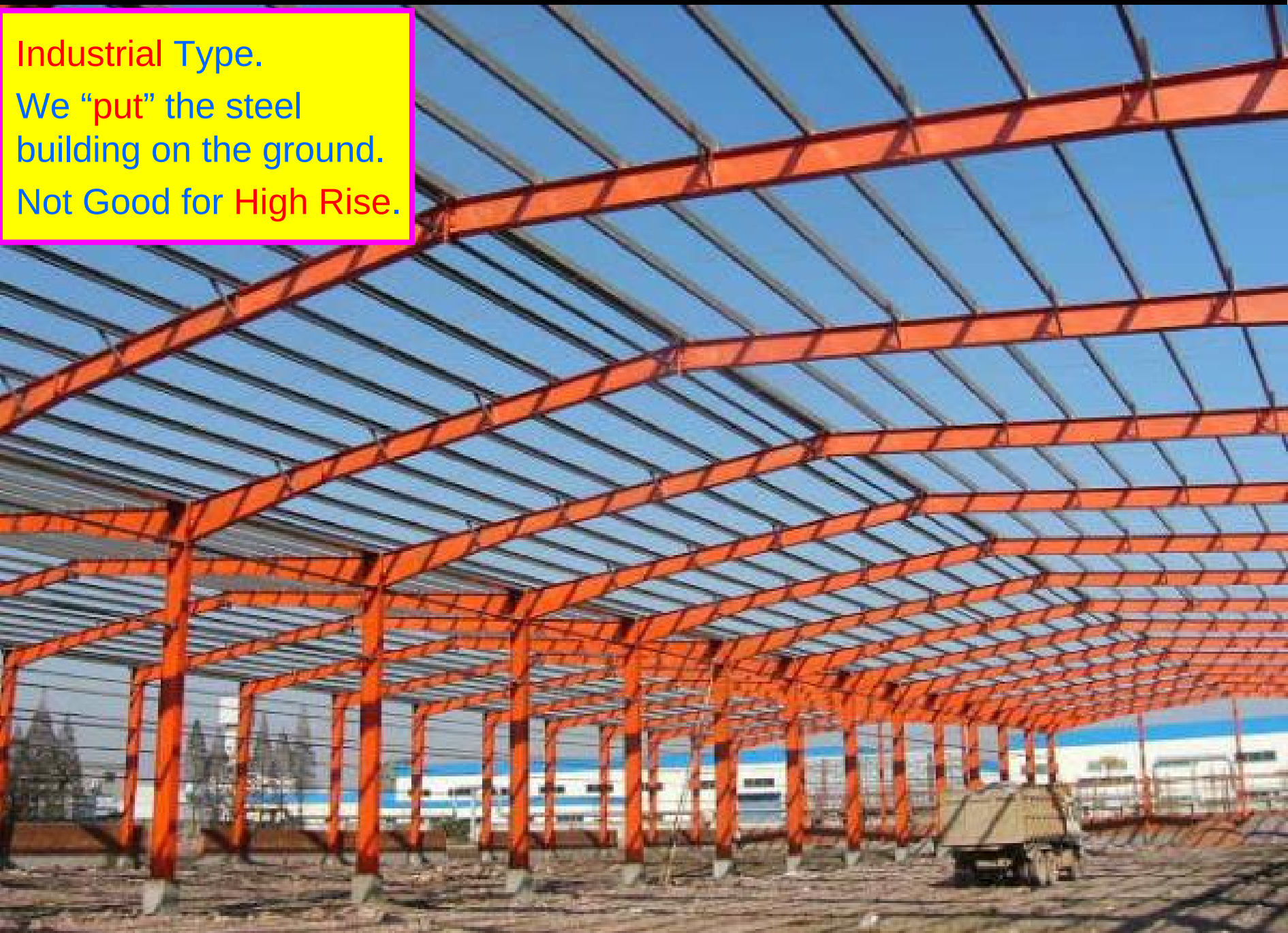
Typhoon in Taipei 2016

Typhoon in Taipei 2016

A Healthy Tree

Which is Safer ?

Imagine two trees of similar size—one with shallow roots and one with deep roots. If a severe windstorm came, which of those trees would be most likely to fall? Why?


Industrial Type.
We “put” the steel building on the ground.
Not Good for High Rise.

Begin from Basement

B1 Column
Roots of the steel building


1.8m * 1.8m
SRC column
B1 Column
Roots of the steel
building


1.8m * 1.8m
B1 SRC column

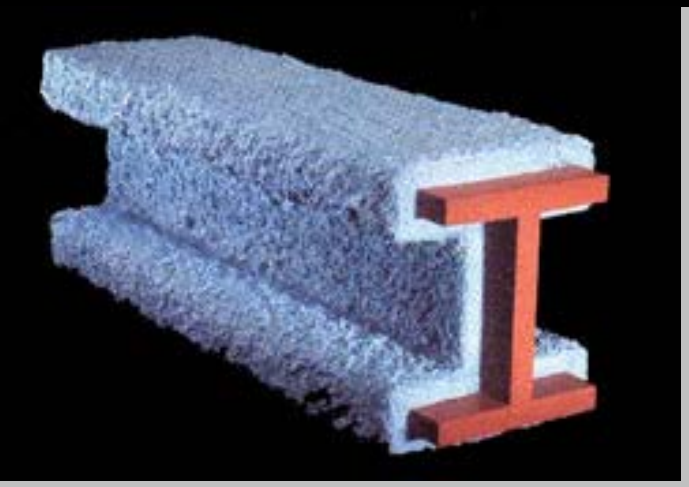
Fire Protection

Fire Rating	
Column, Girder, Beam	2 Hour
Floor	2 Hour
Dry Wall (fire fighting lobby, etc.)	2 Hour
(others)	1 Hour

Fire Protection

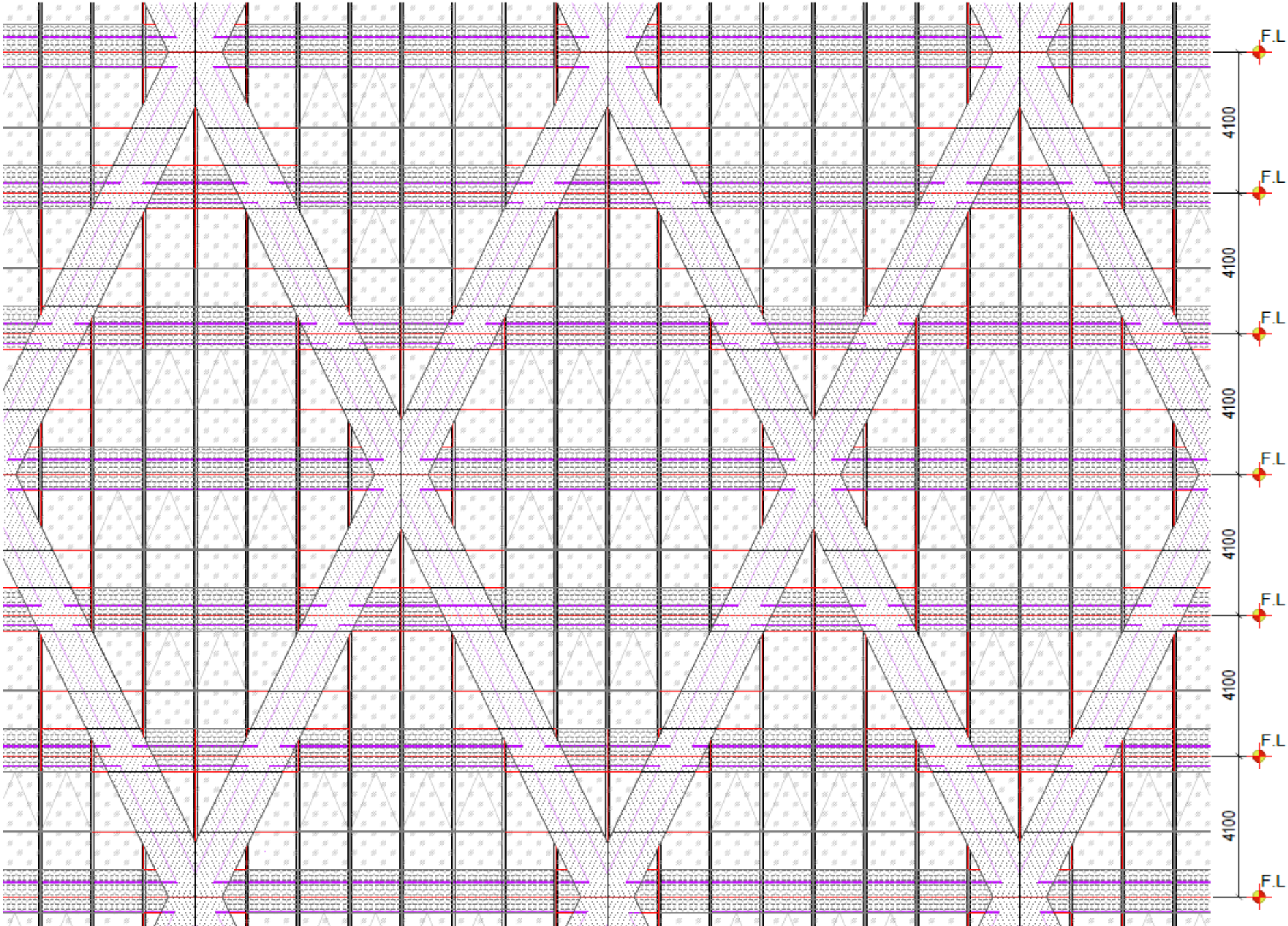
Steel Structure

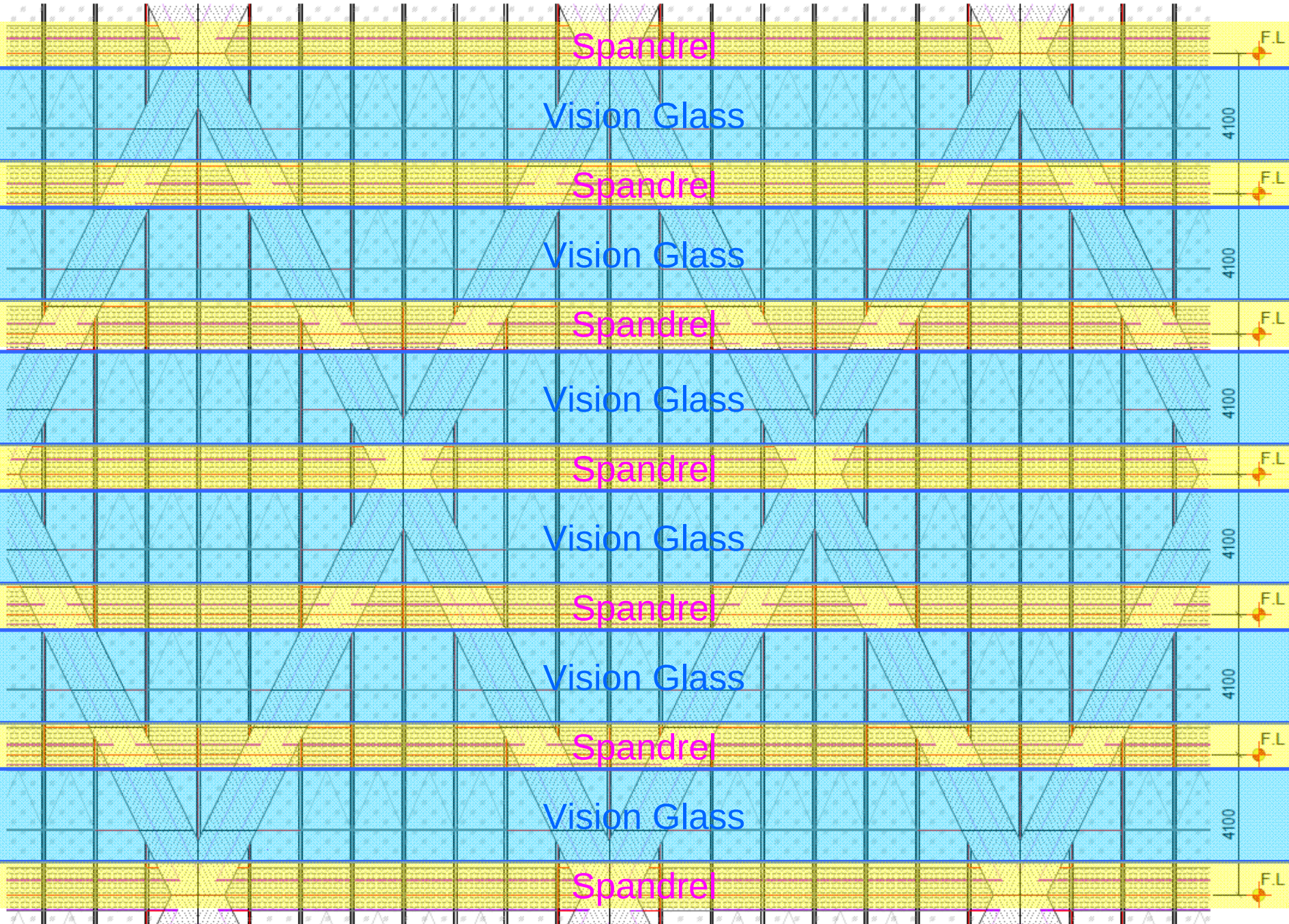
Fire Proof Foam



Fire Protection

Curtain wall


F.L
4100
F.L
4100
F.L
4100
F.L
4100
F.L
4100
F.L


Spandrel
Vision Glass
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Nature of Fire

Smoke

Gas (toxic)

Flame

75% of all fire deaths are caused by smoke inhalation.

47% of survivors caught in a fire could not see more than 12 feet (3.6 m).

Approximately 57% of people killed in fires are not in the room of the fire's origin.

Smoke

Smoke travels 120~420 feet per minute (36~128 m/min), under fire conditions.

Poke through effect

This is where flame and hot gasses penetrate through openings in fire-rated walls and floor/ceilings to ignite combustibles on the other side.

Chimney effect

This is where heated surfaces create thermal zones that include upward air movement, which in turn sucks hot gasses and flames in its direction. This effect is attributed to the spread of fire upward through shafts, and also the spread of fire upward through available openings between the floor slab edge and the curtain wall.

Leapfrog effect

This effect is apparent in mid- to high-rise building fires where flames blasting out through perimeter windows ultimately reach back in through the windows above and continue to spread vertically to upper floors.

Poke through effect

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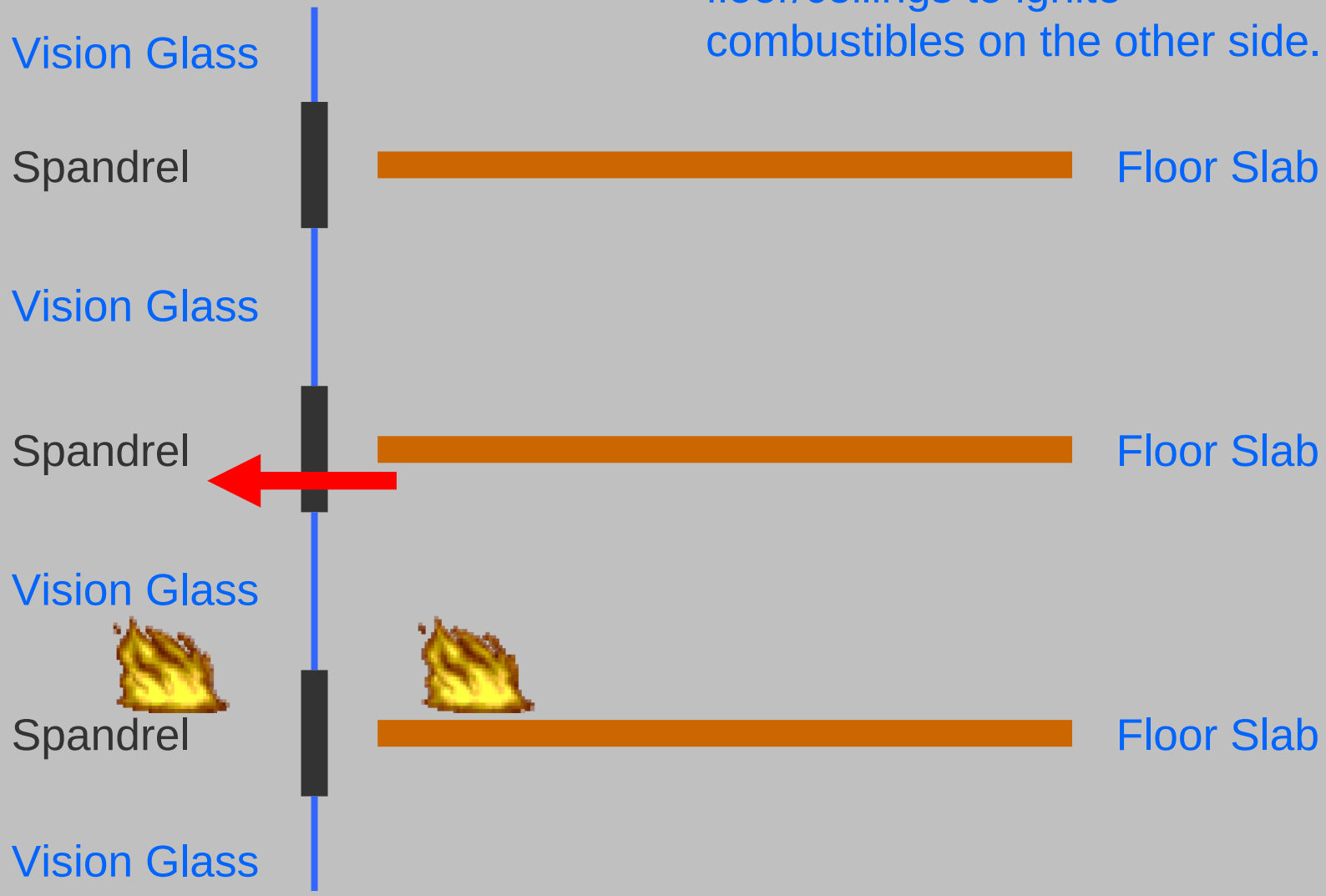

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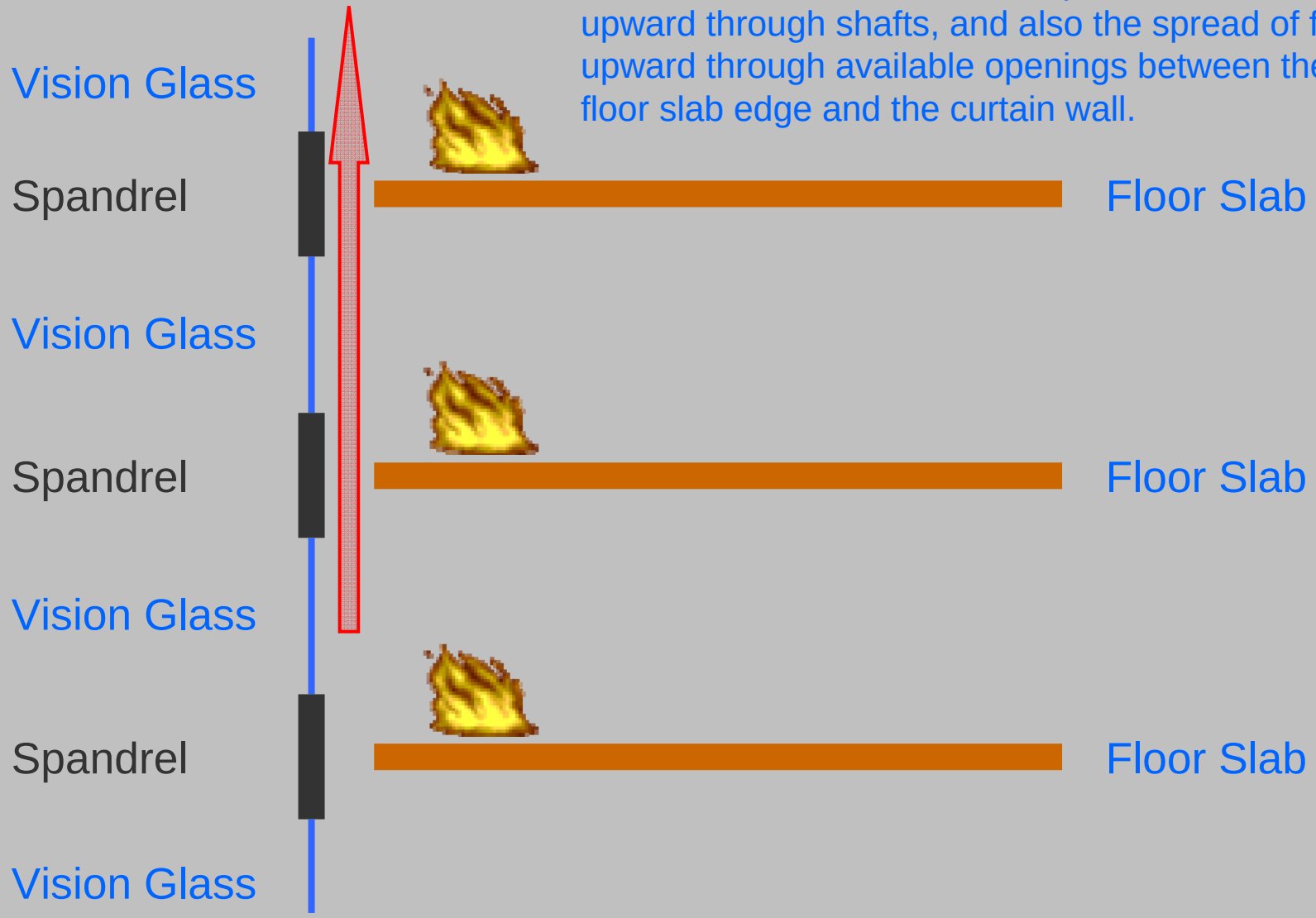

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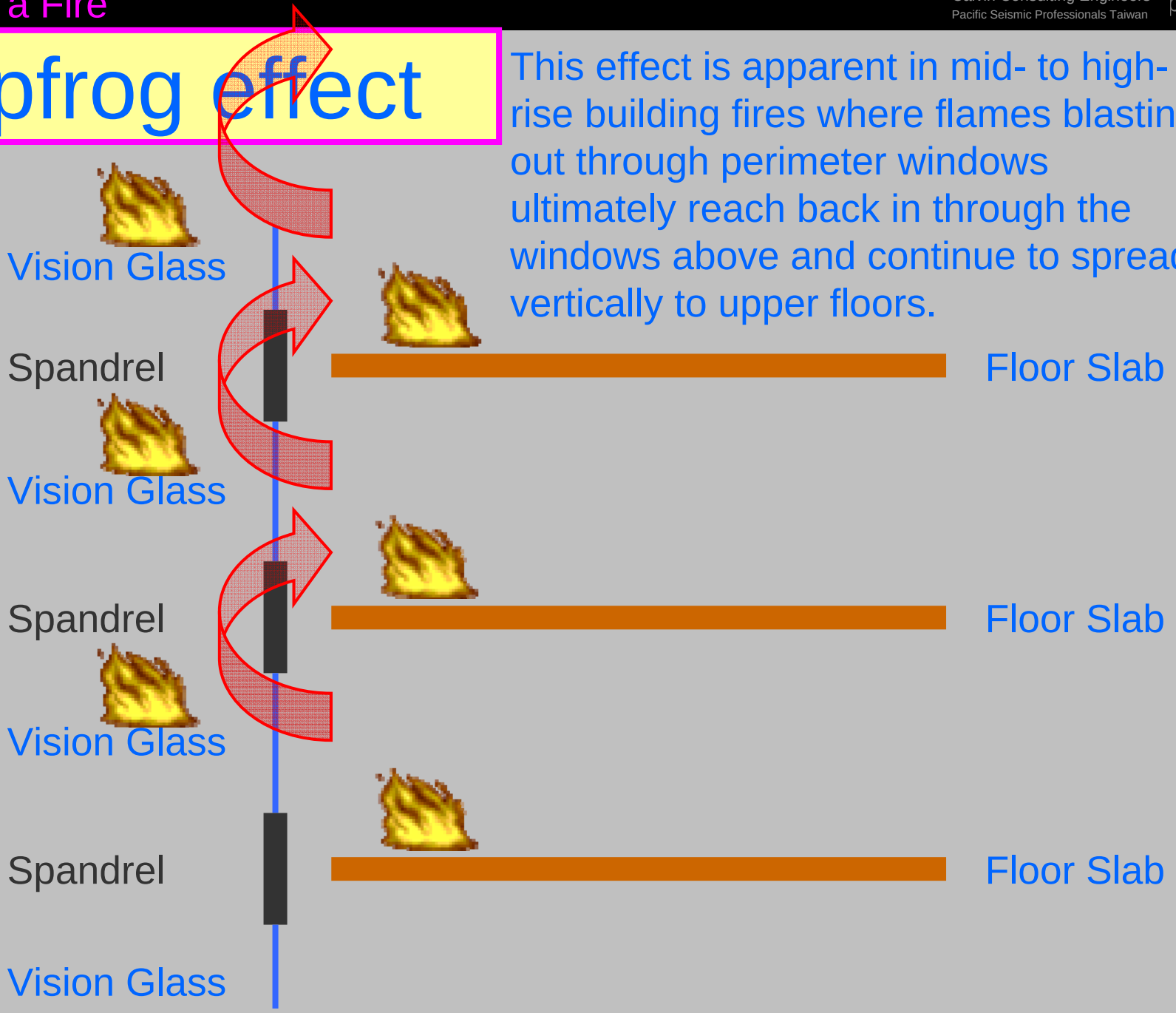


Leapfrog effect

MGM Grand Hotel Fire, Las Vegas, 1980/11/21

85 killed, most through smoke inhalation.

Hilton Hotel, Las Vegas, 1981/02/10

Fire spread from 8th to 13th floor in 25 minutes. 8 killed.

First Interstate Bank, Los Angeles, 1988/05/04

Flames spread from 13th to 16th floor via perimeter joint. 1 killed.

One Meridian Plaza, Philadelphia,

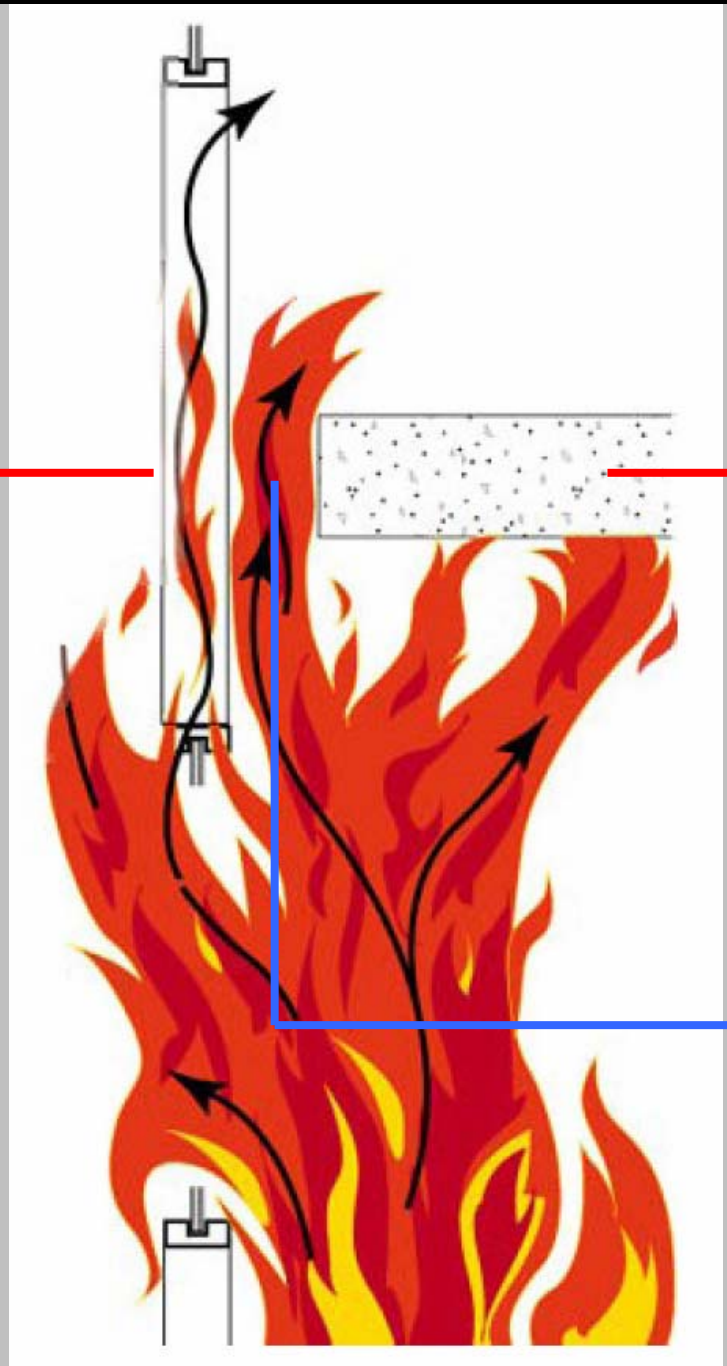
Fire spread from 22nd to 30th floor through unprotected openings including slab edge.

Lesson Learned (Technical Report, U.S. Fire Administration, 1988)

1. Sprinkler system: use the protection as soon as possible.
2. Unsprinklered highrise fires create massive staffing requirements.
3. High danger to firefighters was mitigated by physical fitness, good personal safety equipment, and safety training.
4. ICS is critical for a large, complex fire.
5. Communications within and from a steel frame building still can be a problem.
6. Radio communications can easily be overloaded without strict radio discipline and an adequate number of channels.
7. Building personnel must be trained to take appropriate actions when alarms are activated.
8. Fire-resistive structures can maintain structural integrity if built well.
9. Protected elevators are needed for fire service use.
10. Smoke in stairways is still a problem.
11. Fire departments should develop contingency plans that contemplate the failure of systems to perform as designed, especially for major buildings.

12. Vertical and horizontal fire spread can still be rapid in modern buildings without sprinklers and without adequate compartmentation.

13. Old Lesson: Fire protection systems need to be tested regularly.
14. Falling glass is a special hazard in highrise fires.
15. A major highrise fire requires a heavy commitment of personnel to logistics functions.
16. “Fire-proof” vaults worked well to save valuable papers.
17. Building security personnel must be trained to promptly report fires.

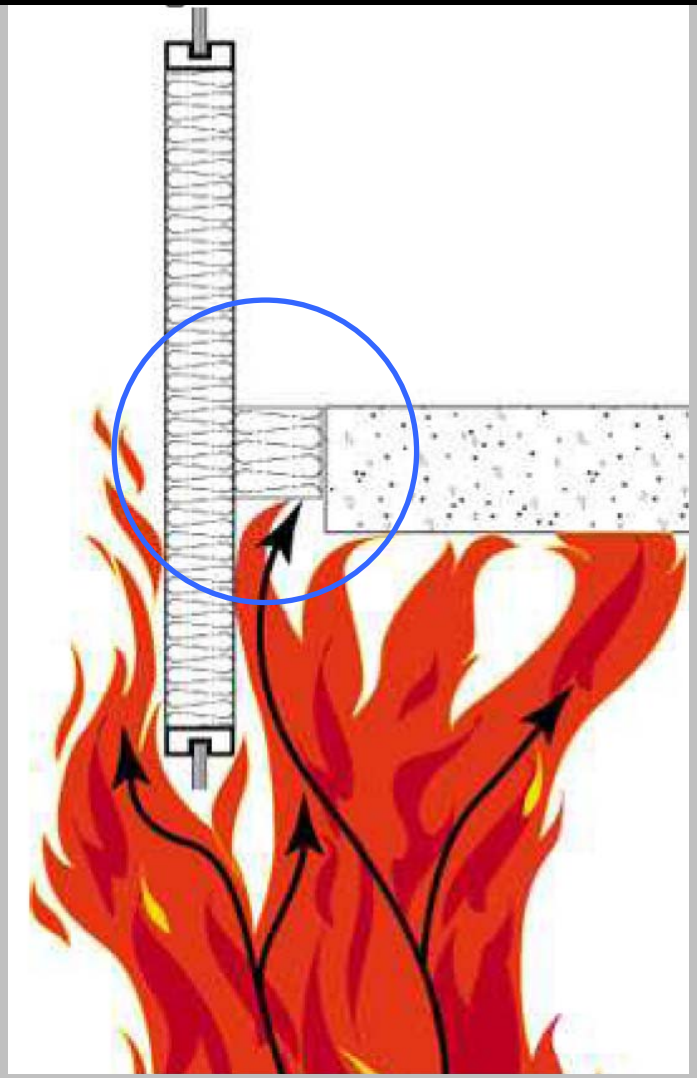


Non-Rated
Curtain Wall

Rated
Concrete Floor

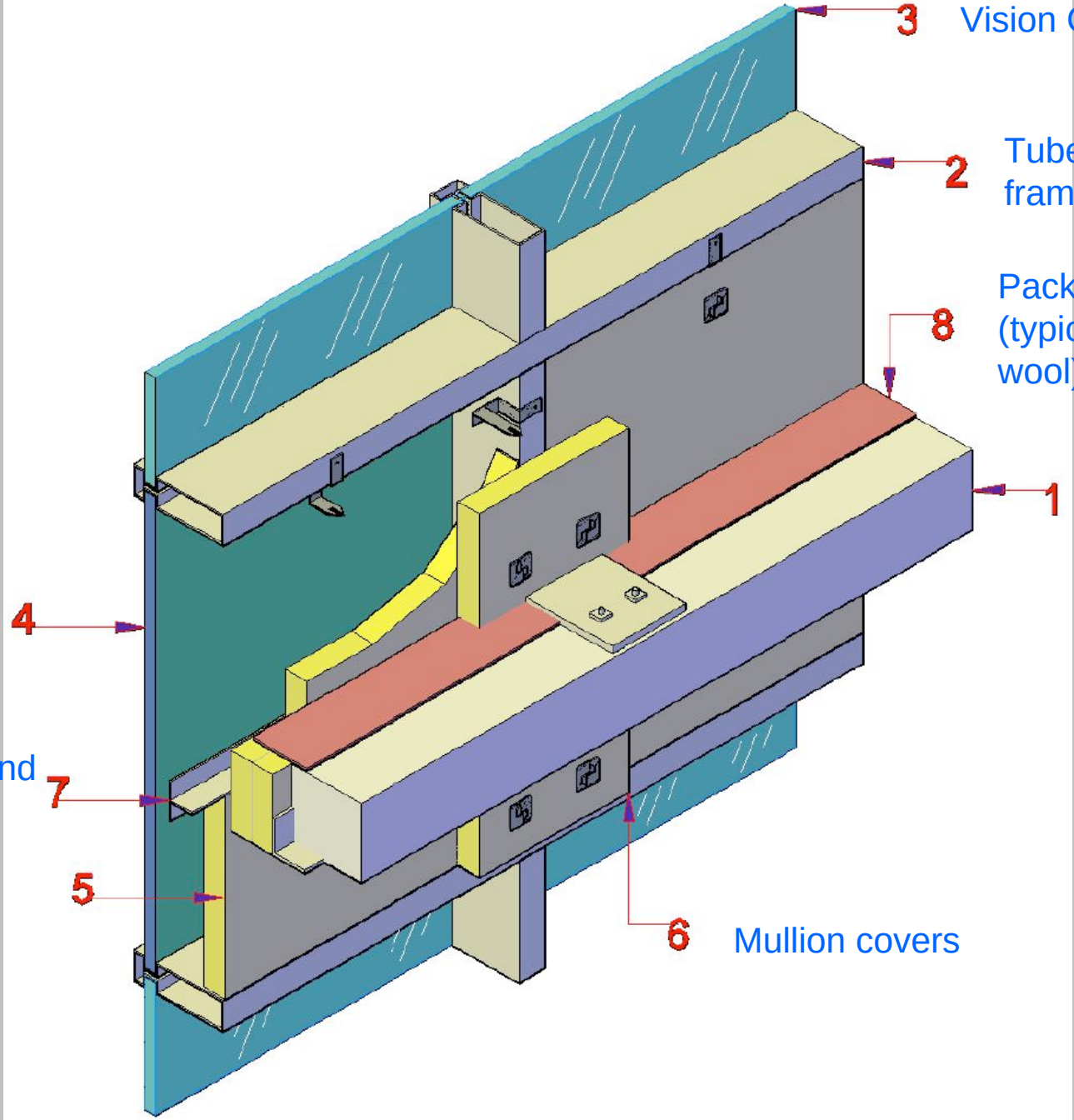
Perimeter Joint

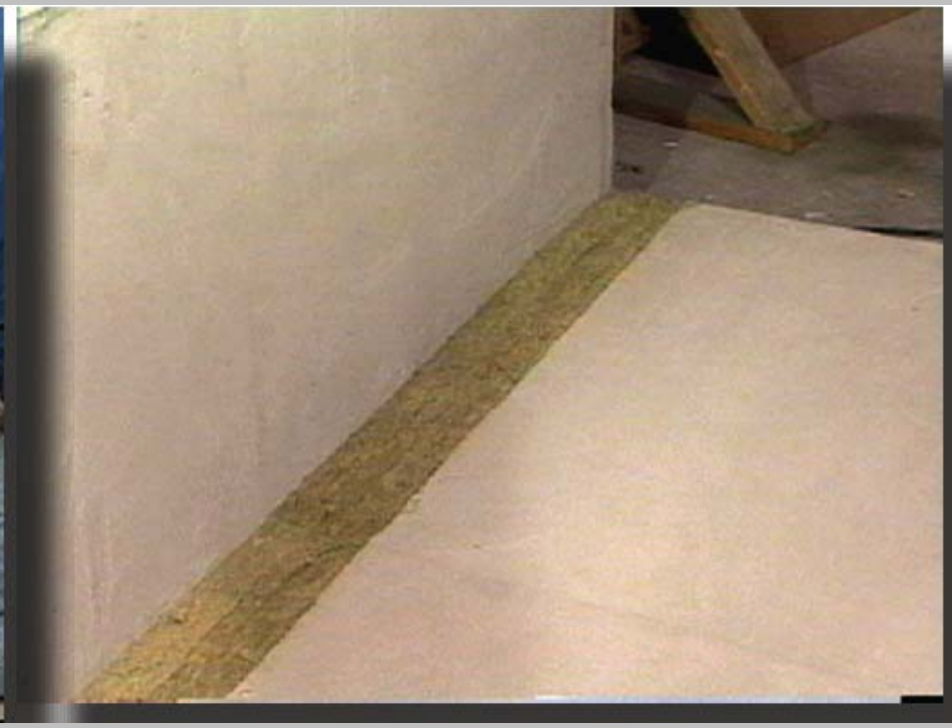
Perimeter Joint Unprotected



Perimeter Joint Protected

A properly designed & tested Perimeter Fire Barrier System not only protects the perimeter joint but critical wall framing and support elements as well!


3
Vision Glass
2
Tube mullion framing system
8
Packing material (typically mineral wool)
1
Fire Resistance Rated floor assembly
4
Spandrel panel (glass, aluminum, stone, etc.)
7
Stiffener behind safing joint
5
Mineral wool insulation
6
Mullion covers



Fire Protection

M & E Duct

M&E duct using Solid Slab (instead of Big Rectangular Opening)

Forming, Damming & Packing Materials

Intumescent Latex Firestop Sealants

Intumescent Latex Firestop Sealants

RC Building

Intumescent Latex Firestop Sealants

RC Building

Thank you very much
for you attention

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