Masterclass in Structural Behaviour
ETS3
3.1 Stability

Cíaran Malik

Third Year, First Term

2019-2020

Schedule

Time	Activity	By	
14:00-14:25	3.1 Stability	Cíaran	
14:30-14:55	3.2 Stability Exercise	Cíaran	
15:00-15:25	3.3 Lighting	Francisco	
15:45-16:00	Tutorials 4, 9, 14, 19	15:50-16:00	Scotts Pine
16:00-16:15	Tutorials 5, 10, 15, 20	16:00-16:10	Redwood
		16:10-16:20	Gum Tree
16:15-16:30	Tutorials 1, 6, 11, 16	16:20-16:30	Grandidier's Baobab
16:30-16:45	Tutorials 2, 7, 12, 17	16:30-16:40	Olive Tree
		16:40-16:50	Himalayan Birch
16:45-17:00	Tutorials 3, 8, 13, 18	16:50-17:00	Bamboo

Key points

1. Horizontal loads

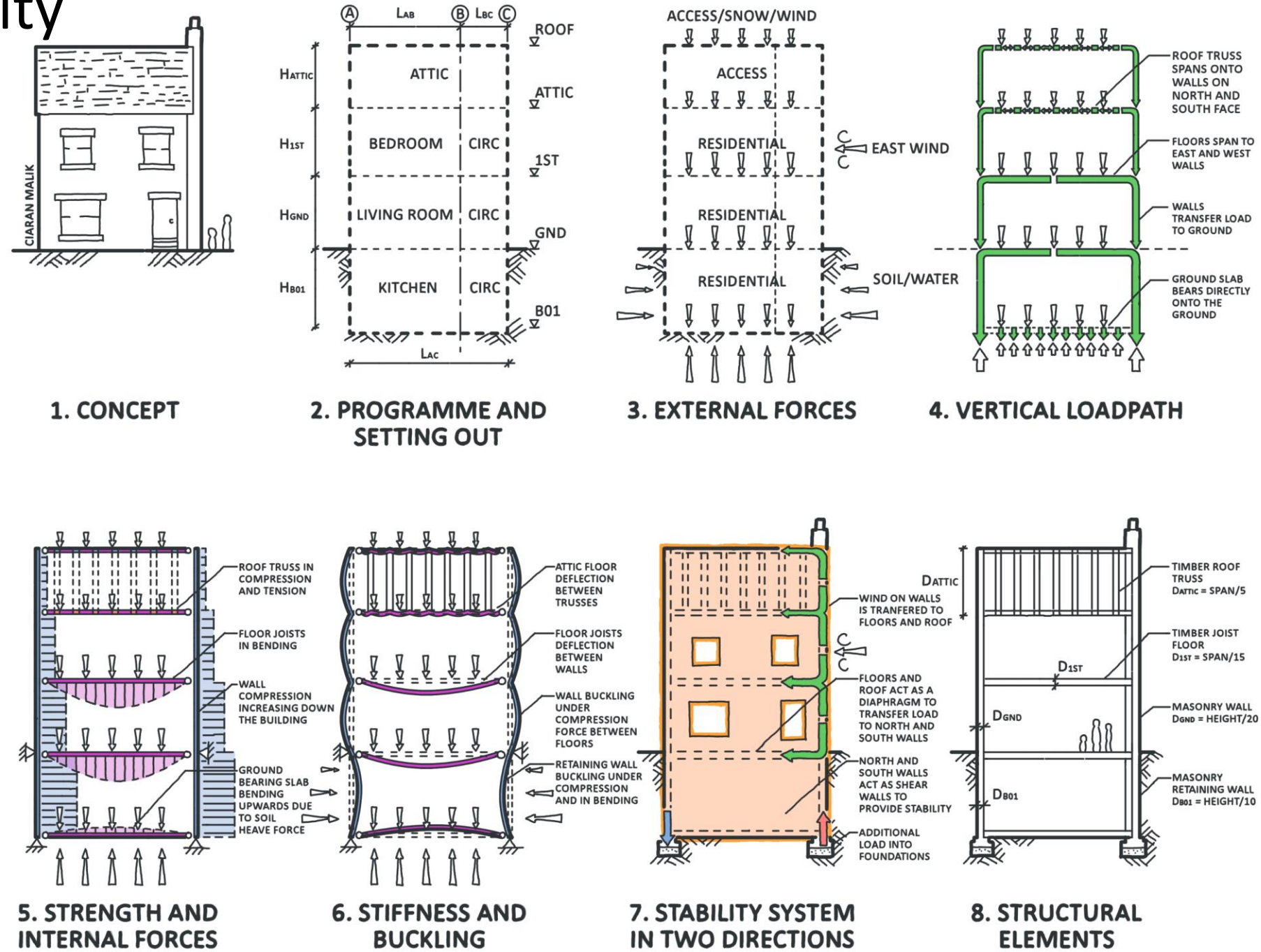
2. Stability systems; shear walls, bracing, outriggers, inherent stability, A-frame, moment frame, cantilever columns.

3. Horizontal load path; façade, diaphragm floor, stability elements

4. Stability in two directions

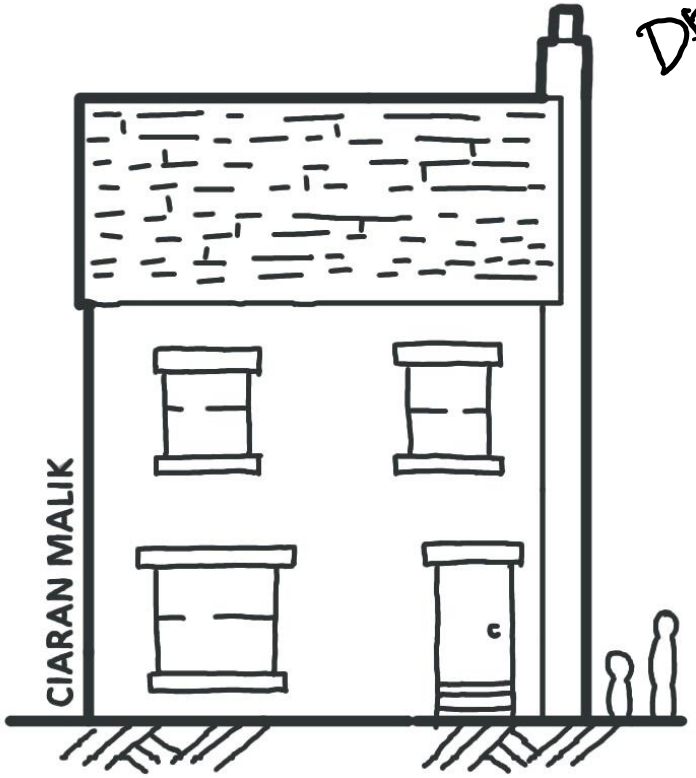
5. Scheme Design

Stability



Design Process Cíaran Malik

Building Loads



DEAD -

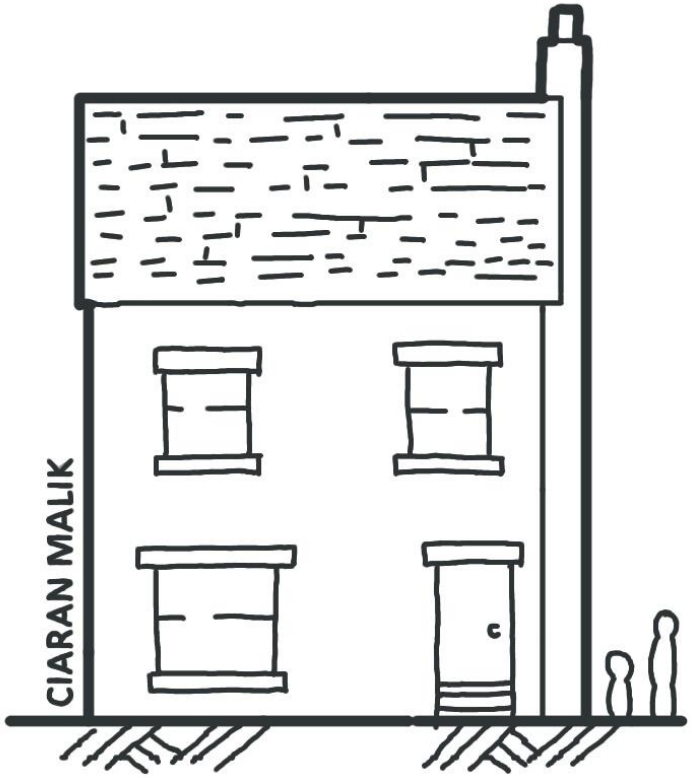
FINISHES

SELFWEIGHT.

LIVE

- PEOPLE/FURNITURE
- RAIN
- SNOW
- WIND.
- SOIL
- FLOODING
- EQ

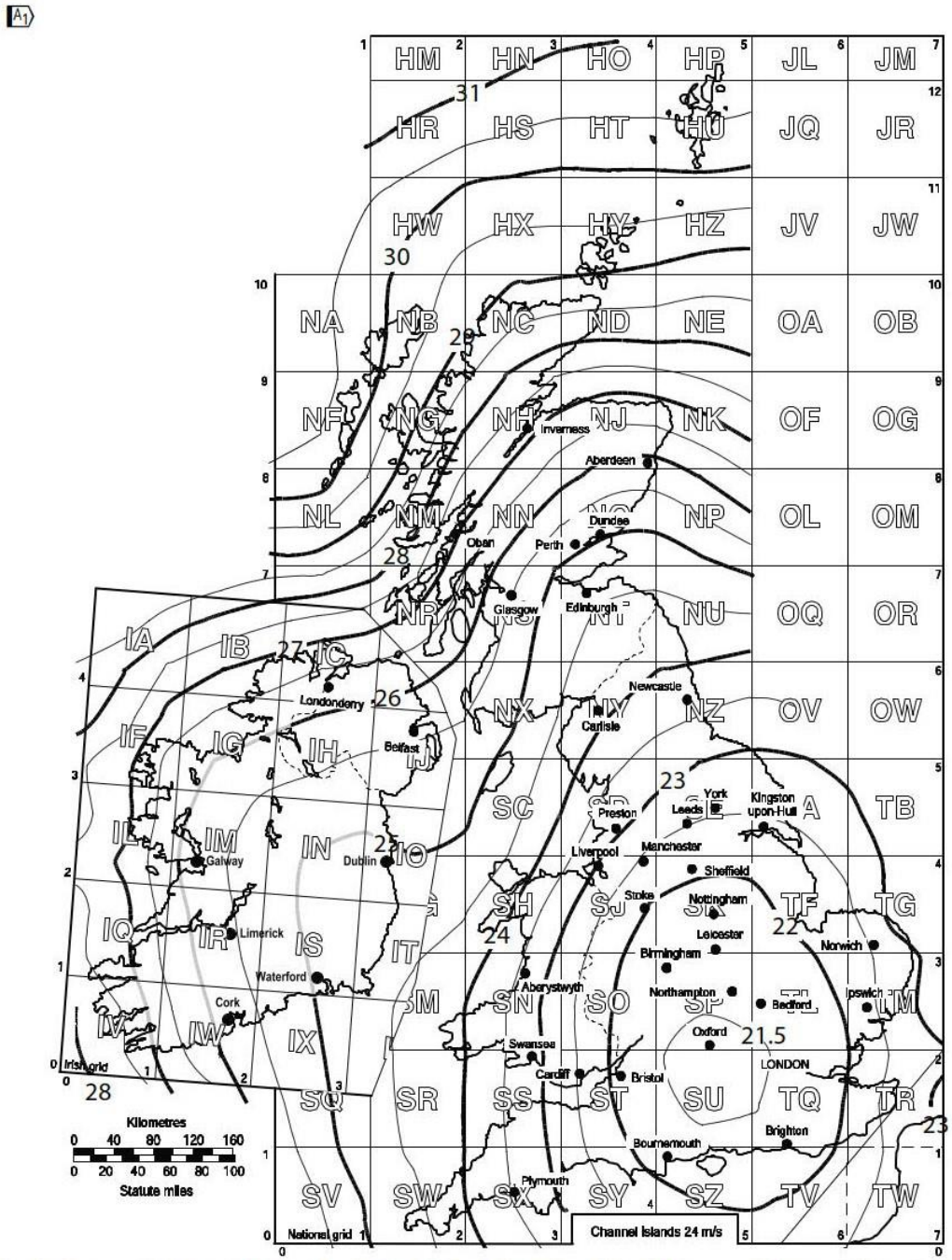
Building Loads



- Self-weight
  - Structure
- Permanent
  - Finishes
  - Services
  - Partitions
- Variable/Live
  - People
  - Vehicles
  - Wind
  - Snow
  - Earthquakes
  - Water
  - Ice
  - Soil
  - Accidental

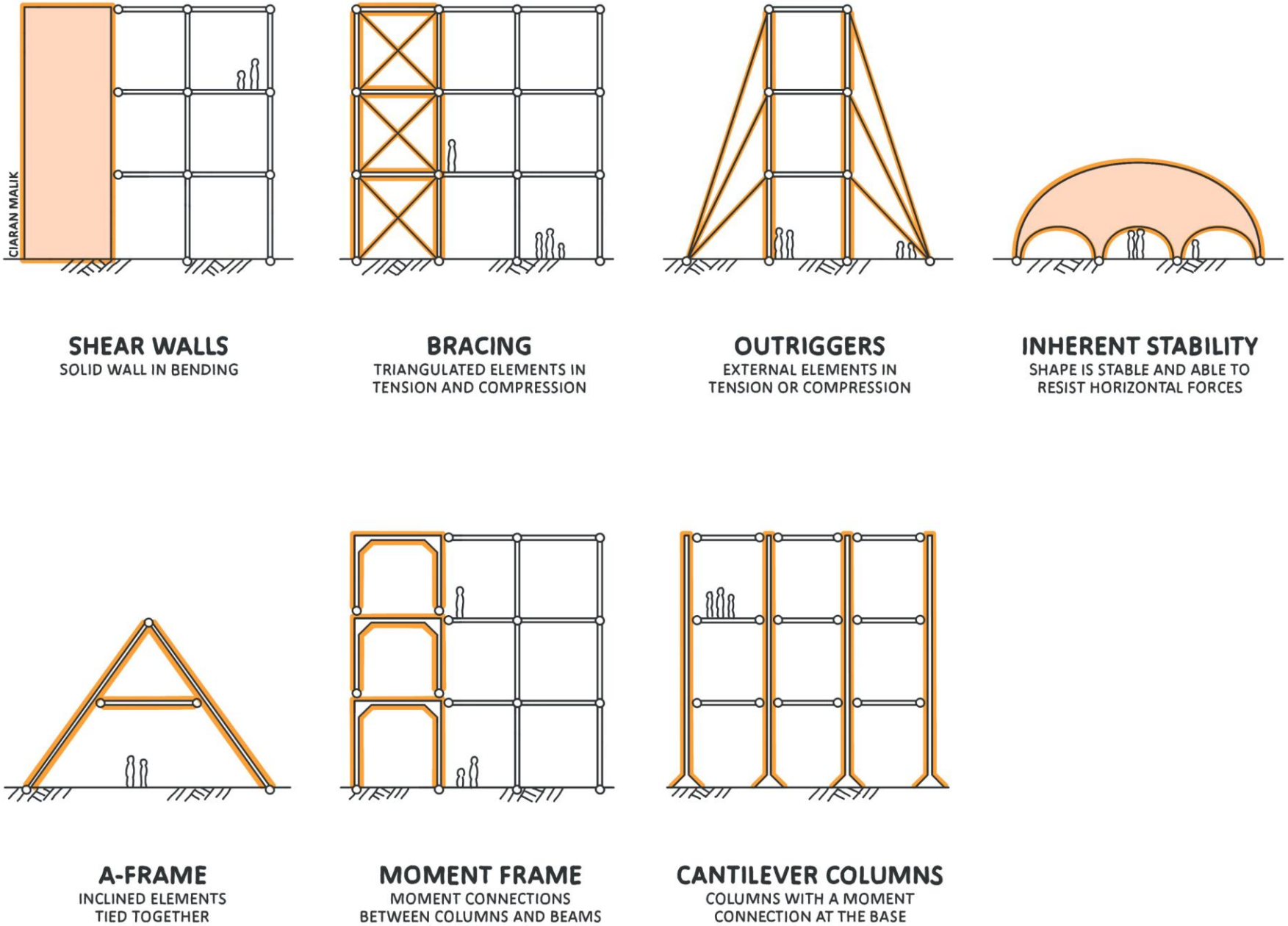
Building Loads
Wind

Figure NA.1 **Value of fundamental basic wind velocity $v_{b,map}$ (m/s) before the altitude correction is applied**



BS EN 1991-1-4 UK NA 2005 +A1 2010 Wind on Structures page 5

Stability Systems



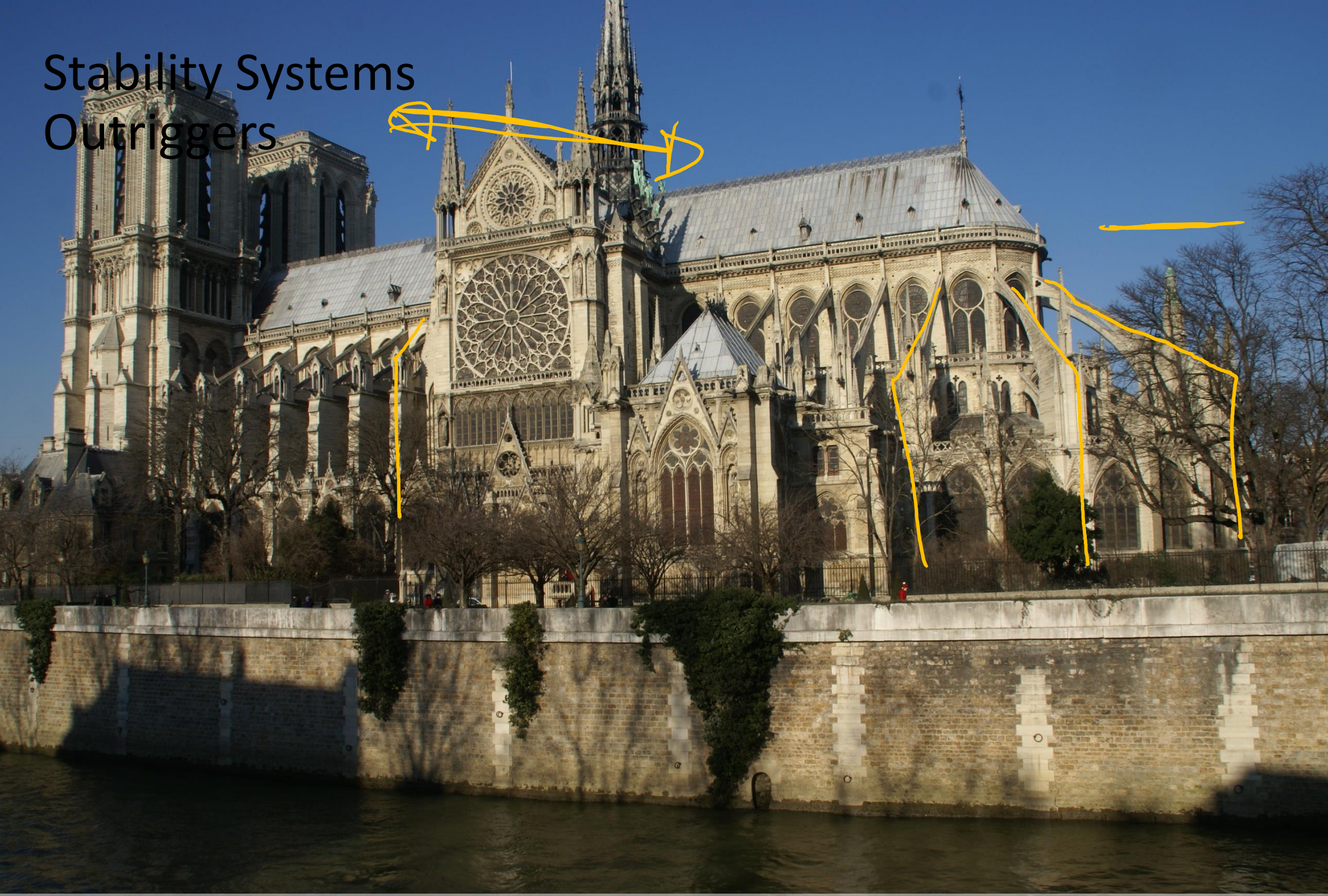
Stability Systems
Shear Walls

Stability Surface-Active, Concrete Shear Wall, Trellick Tower, Erno Goldfinger (Photo Mark Ahsmann)

Stability Systems
Bracing

Stability Vector-Active, Steel Bracing, John Hancock Tower, Skidmore, Owings, & Merrill (Photo Joe Ravi CC-BY-SA 3.0)

Stability Systems
Outriggers



Stability Surface-Active, Stone Flying Buttresses, Notre Dame De Paris 1345, (Photo David Baron)

Stability Systems
A-Frame

Form Frame Structure, Timber A-Frame, A-Frame Re-Think in USA 2013 (front), Bromley Caldari Architects

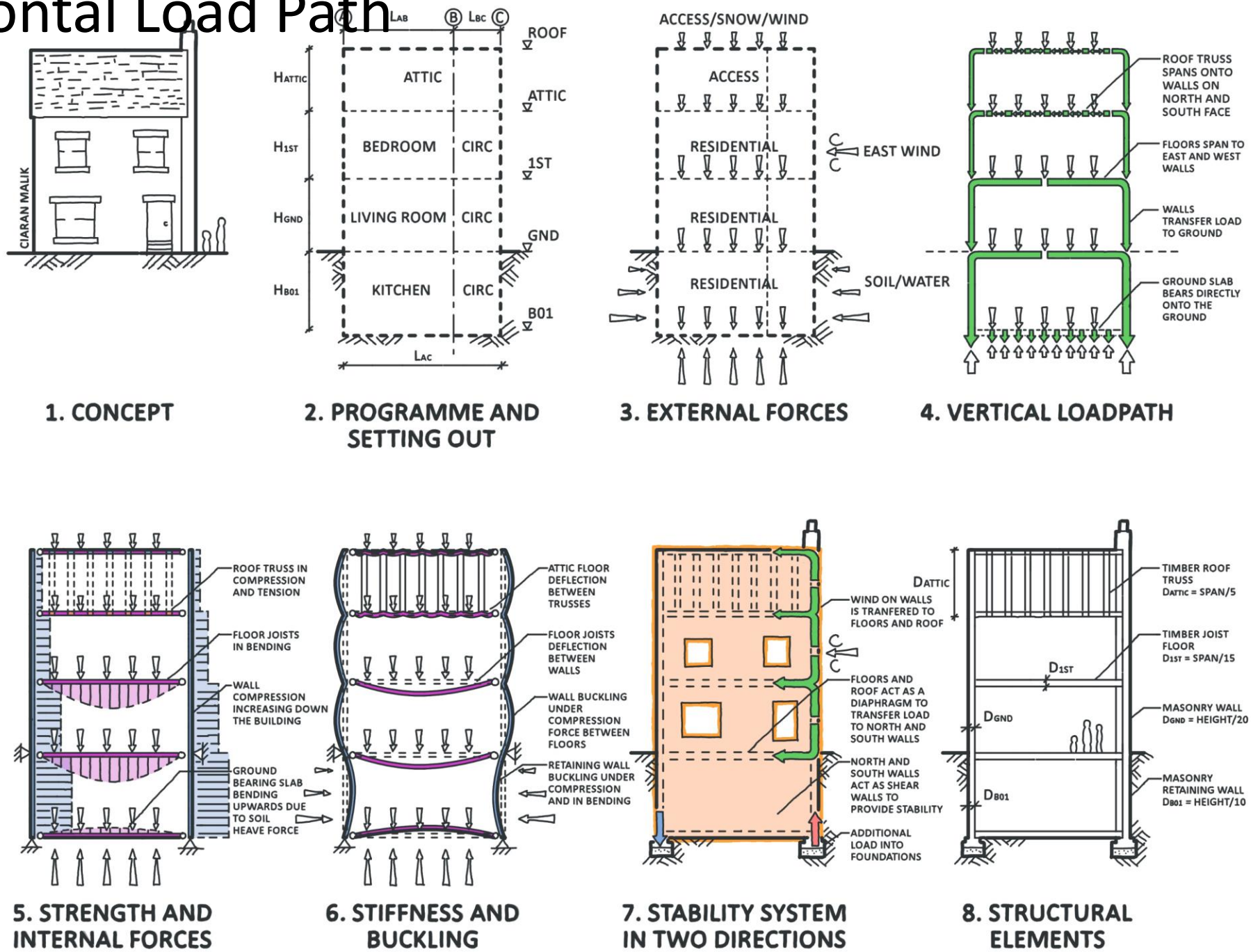
Stability Systems

Form Surface-Active, Masonry Vault, Droneport Prototype 2016, Philippe Block

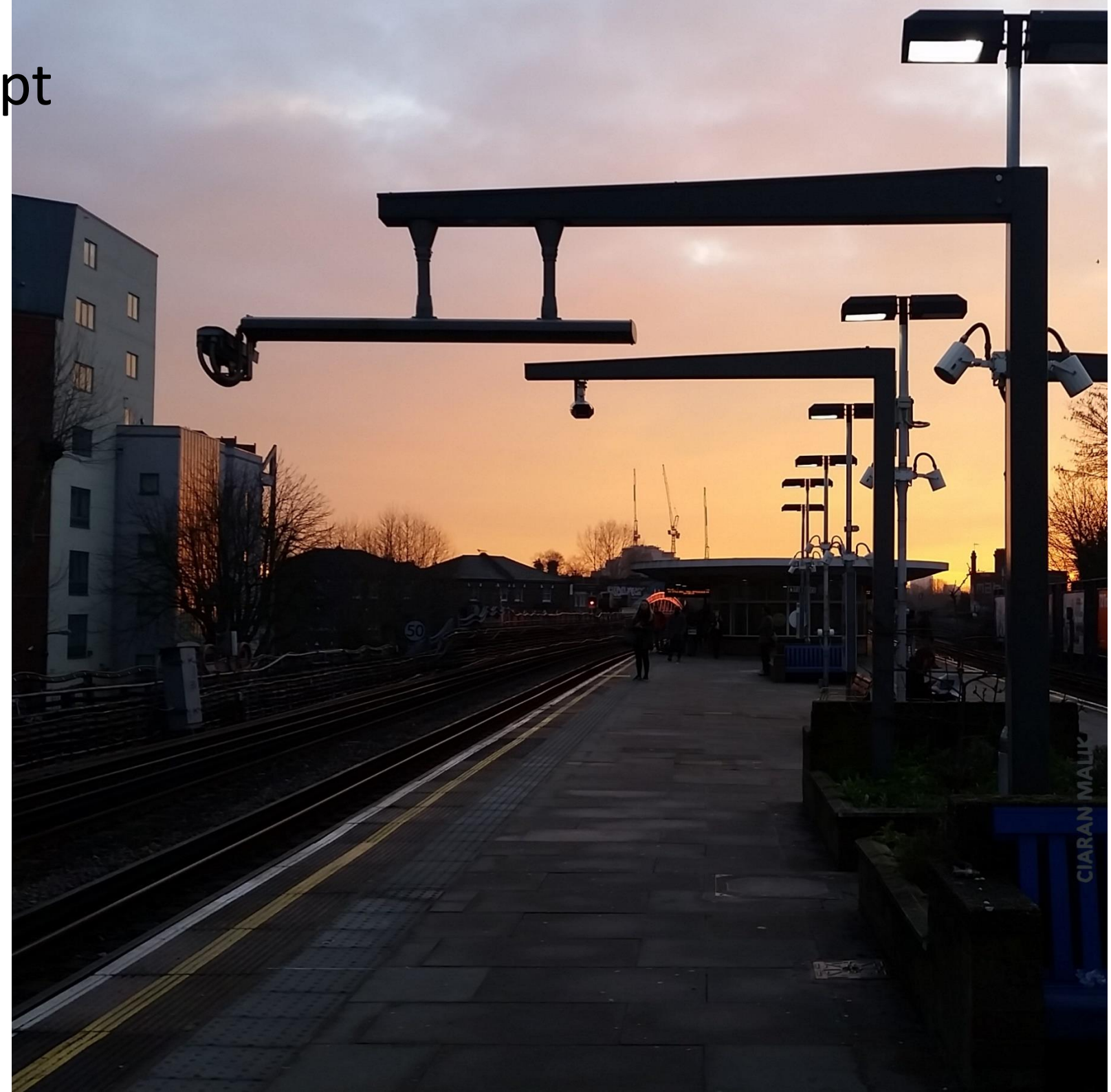
Stability Systems
Cantilever Column

Form Surface-Active, Masonry Arch, Bus Stop (side view), Eladio Dieste

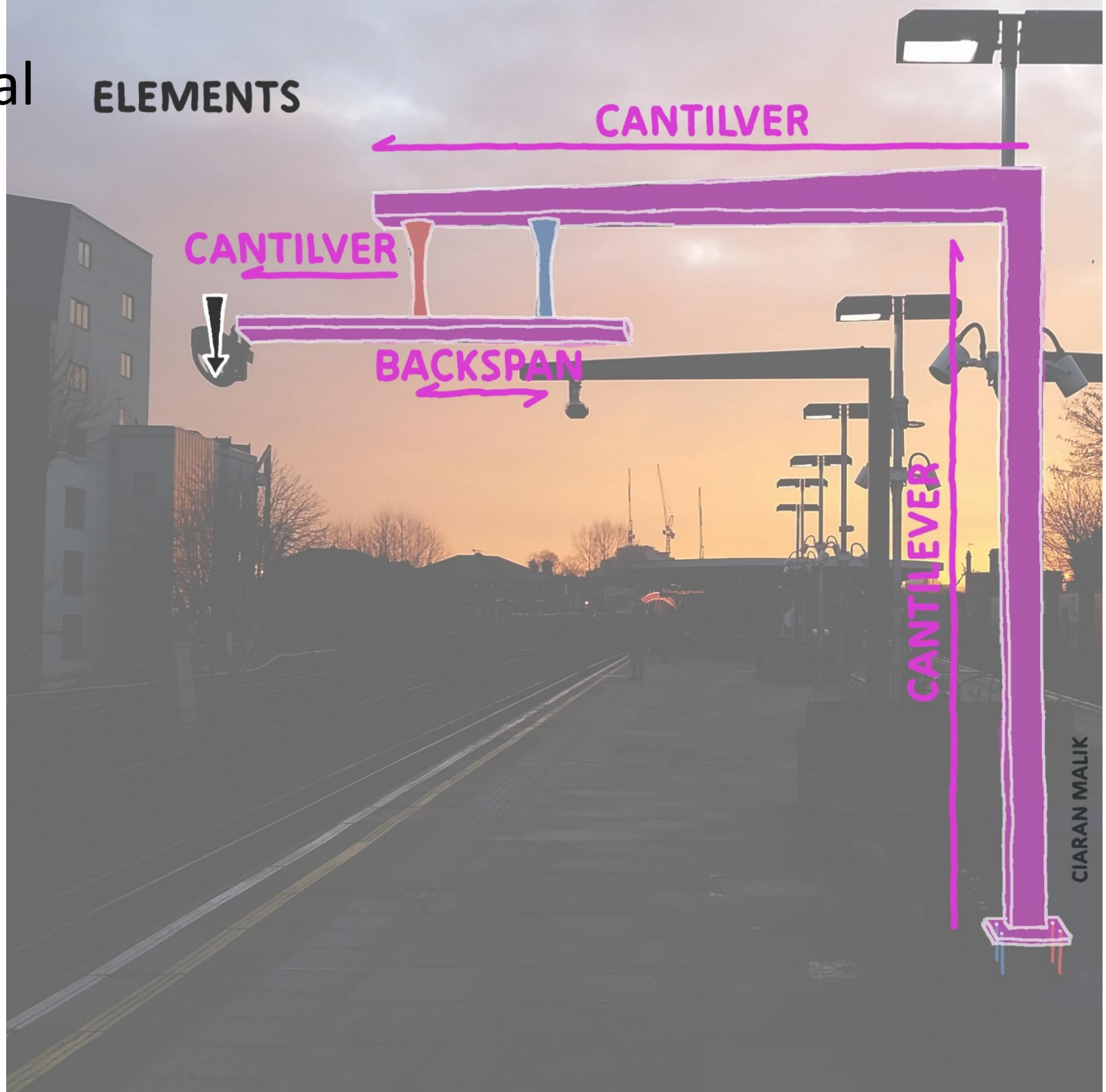
Horizontal Load Path



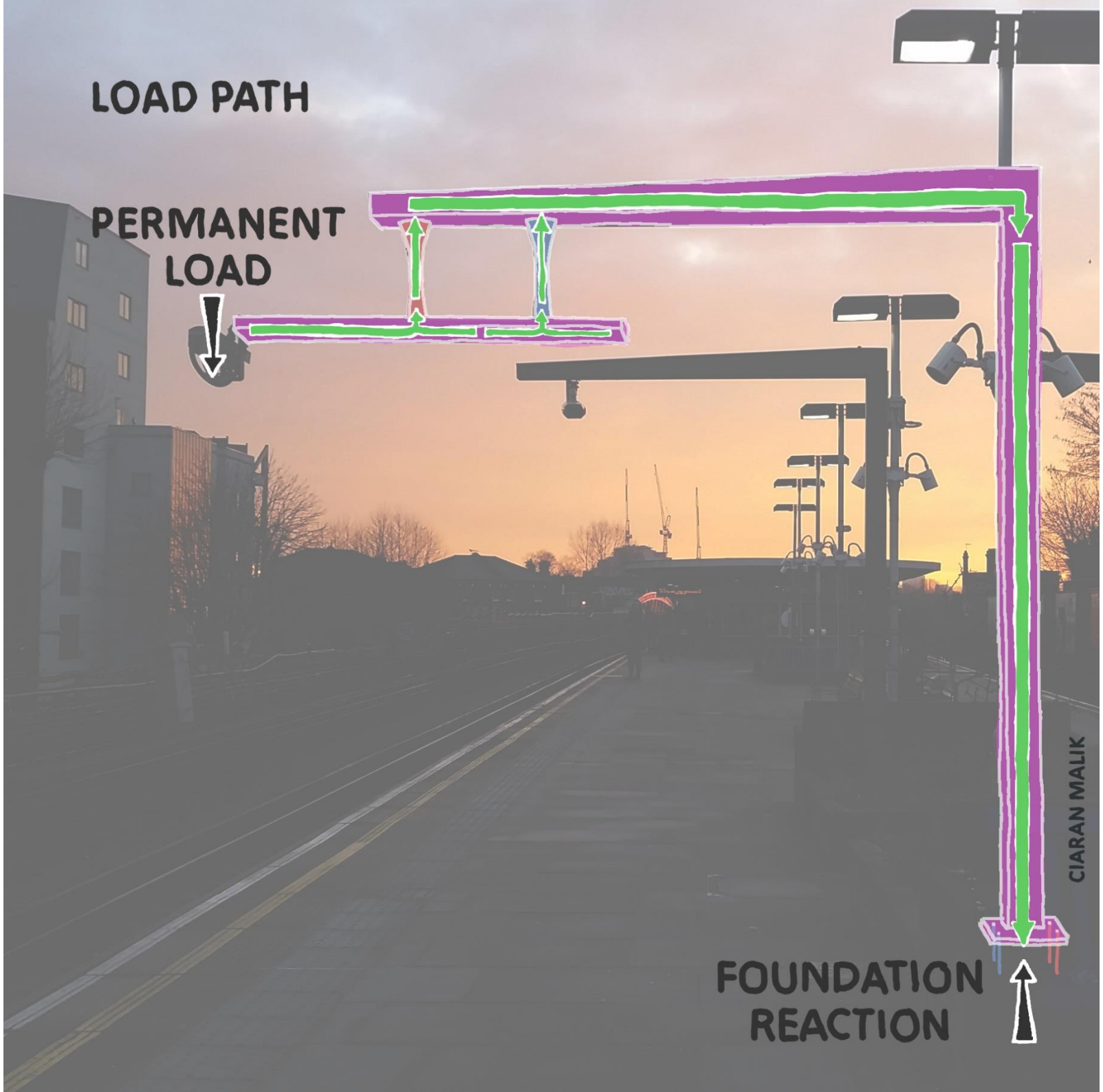
Concept



Internal Forces



Load Path

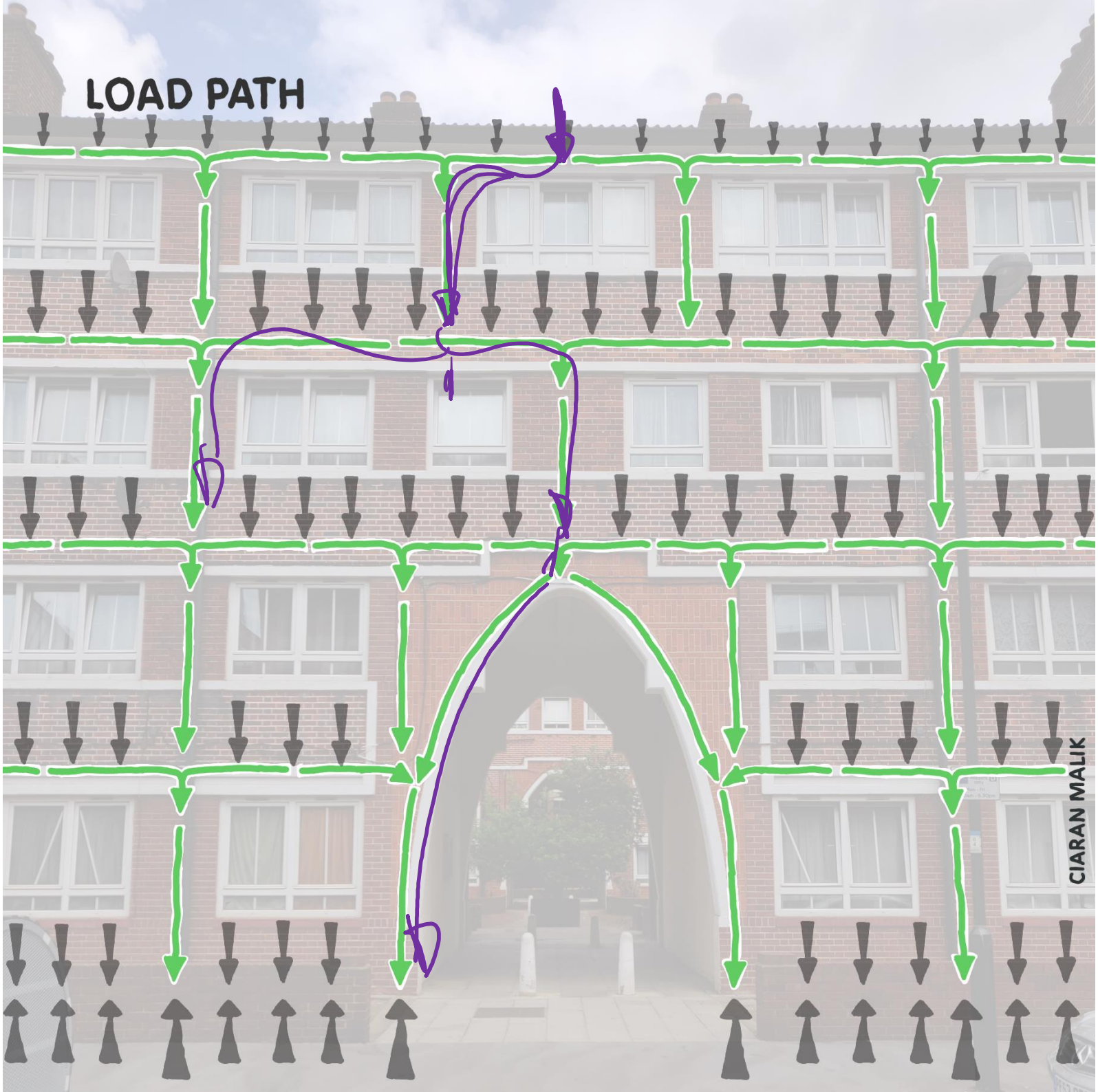

LOAD PATH
PERMANENT LOAD
FOUNDATION REACTION
CIARAN MALIK

Stability

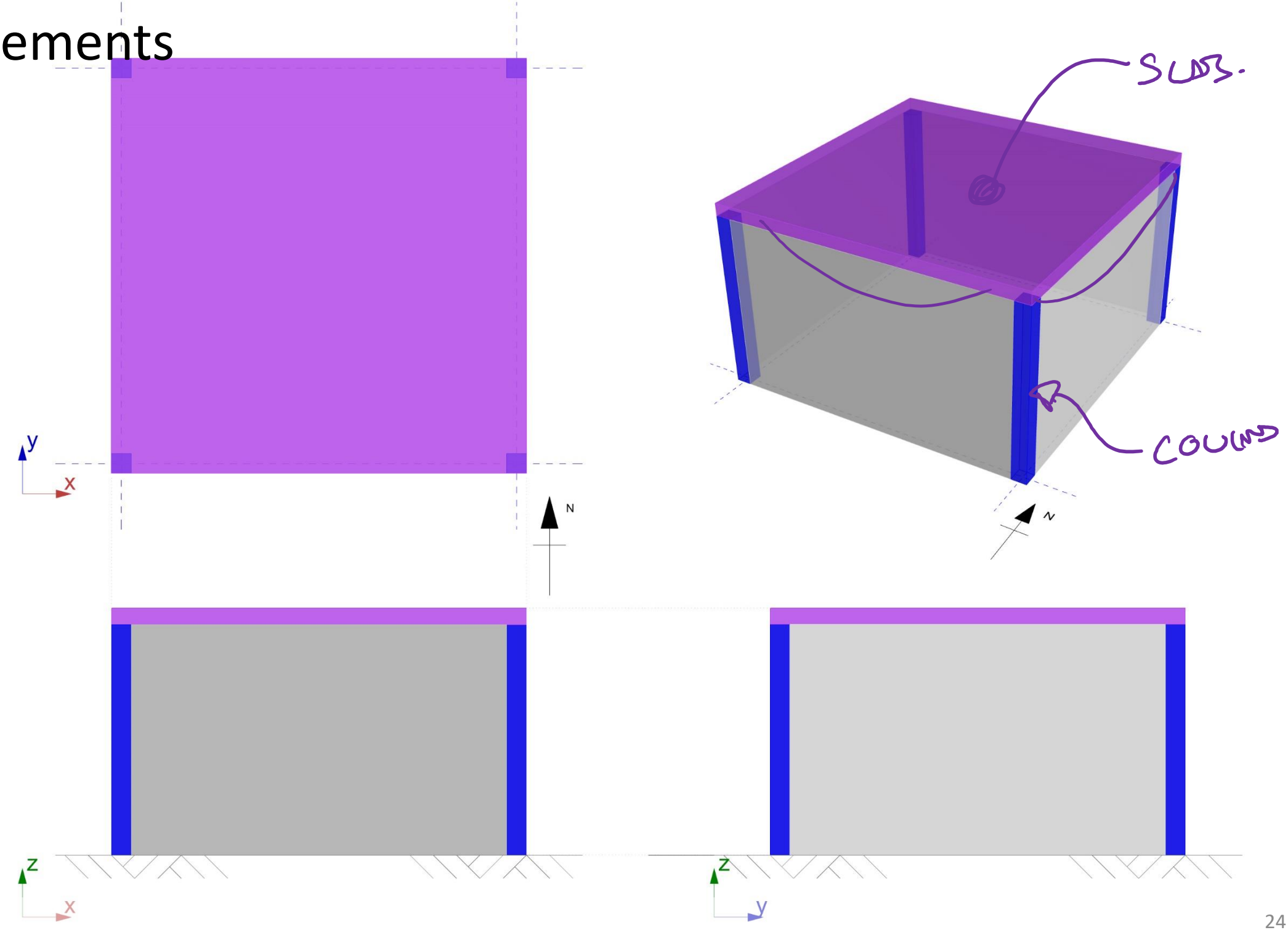
Concept

Internal Forces

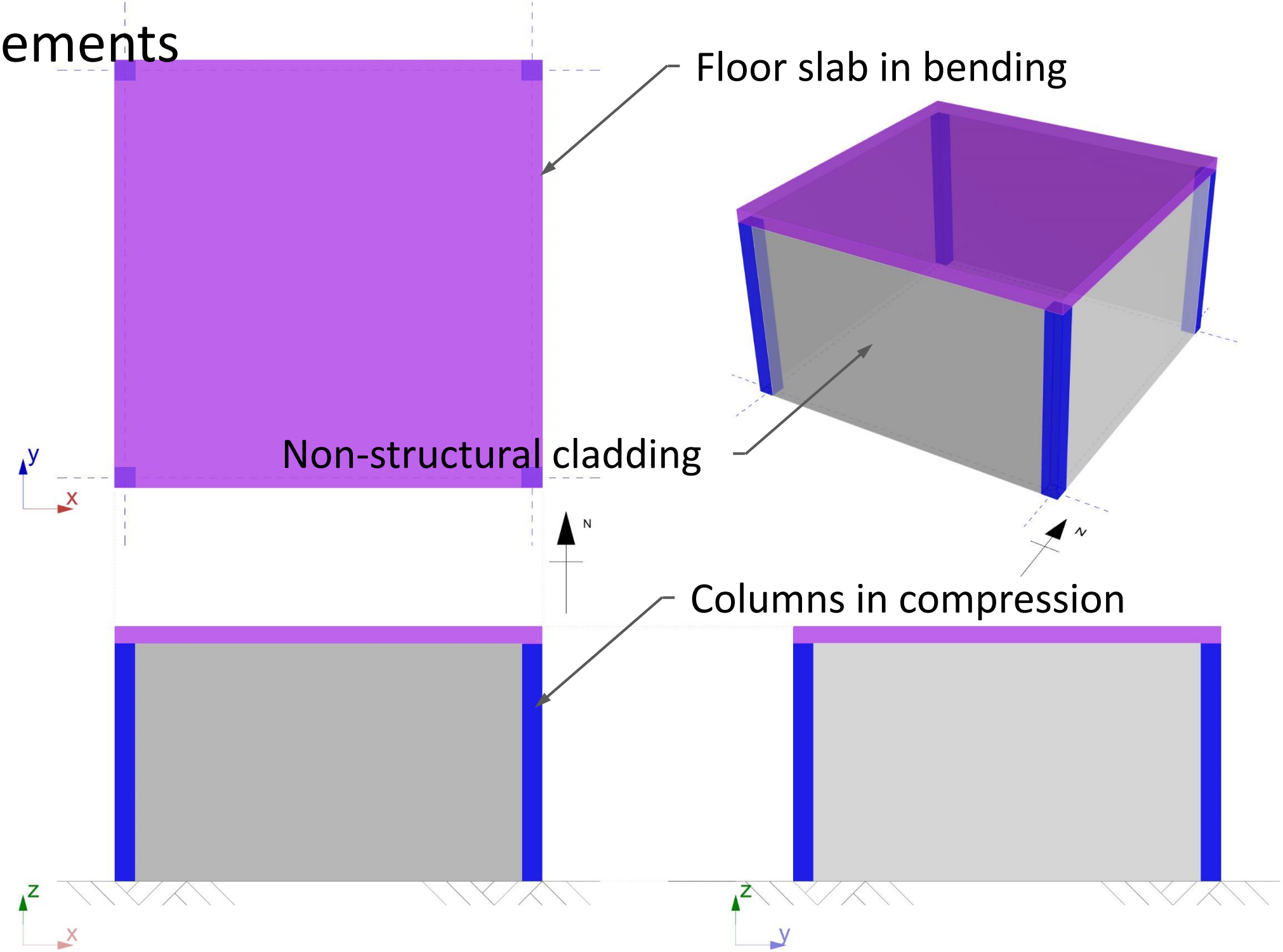
Load Path



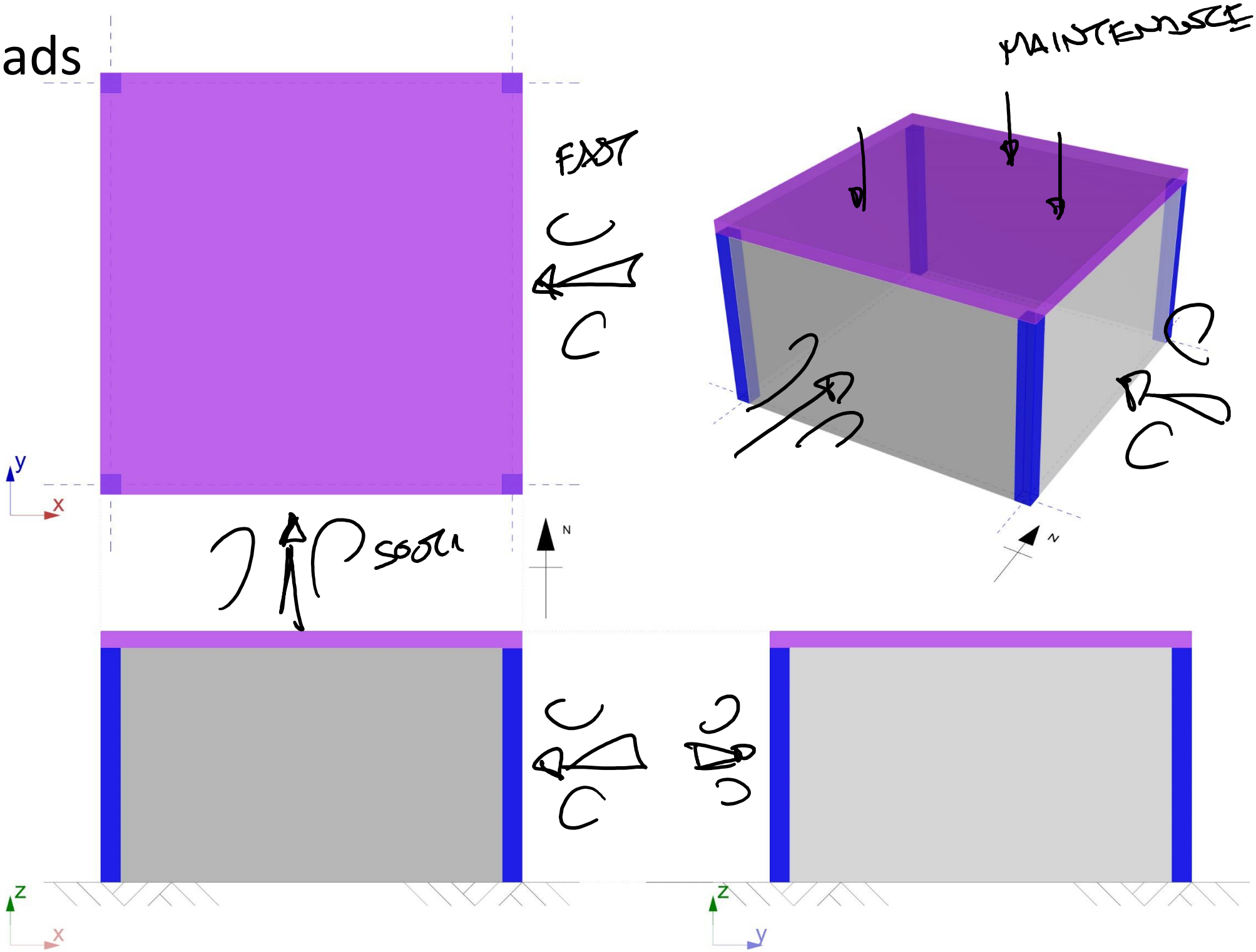
Elements



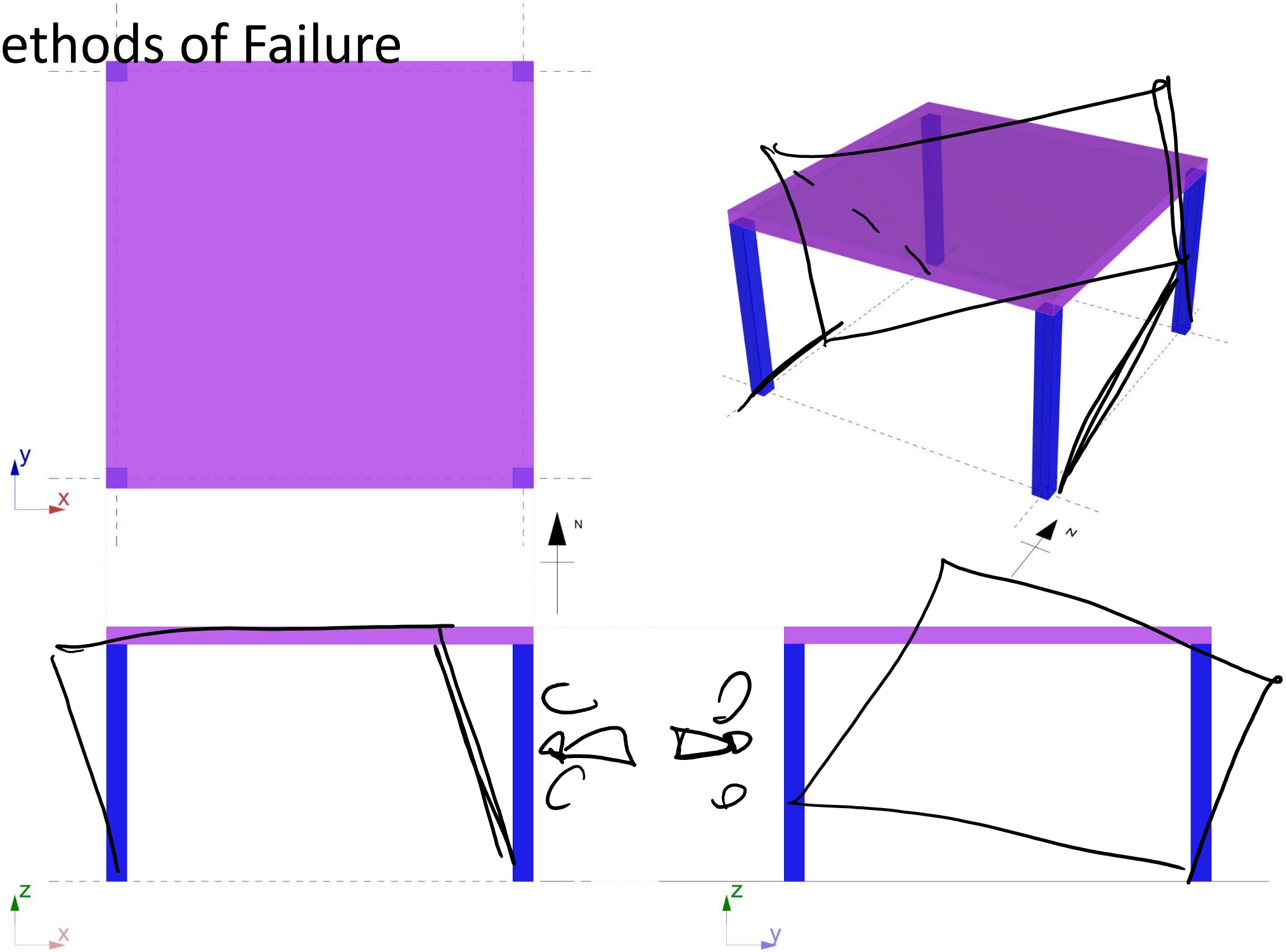
Elements


Floor slab in bending
Non-structural cladding
Columns in compression
y
x
N
z
x
z
y

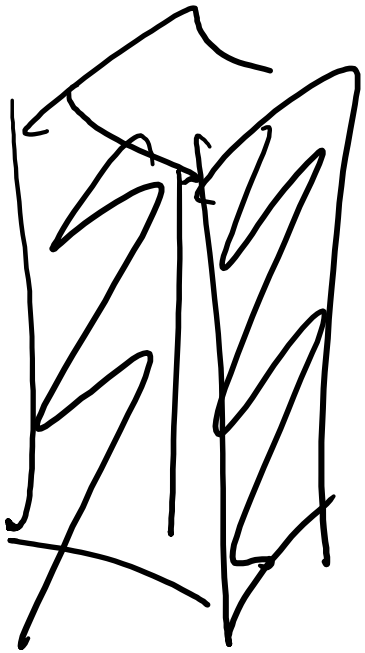
Loads



Methods of Failure



Methods of Failure



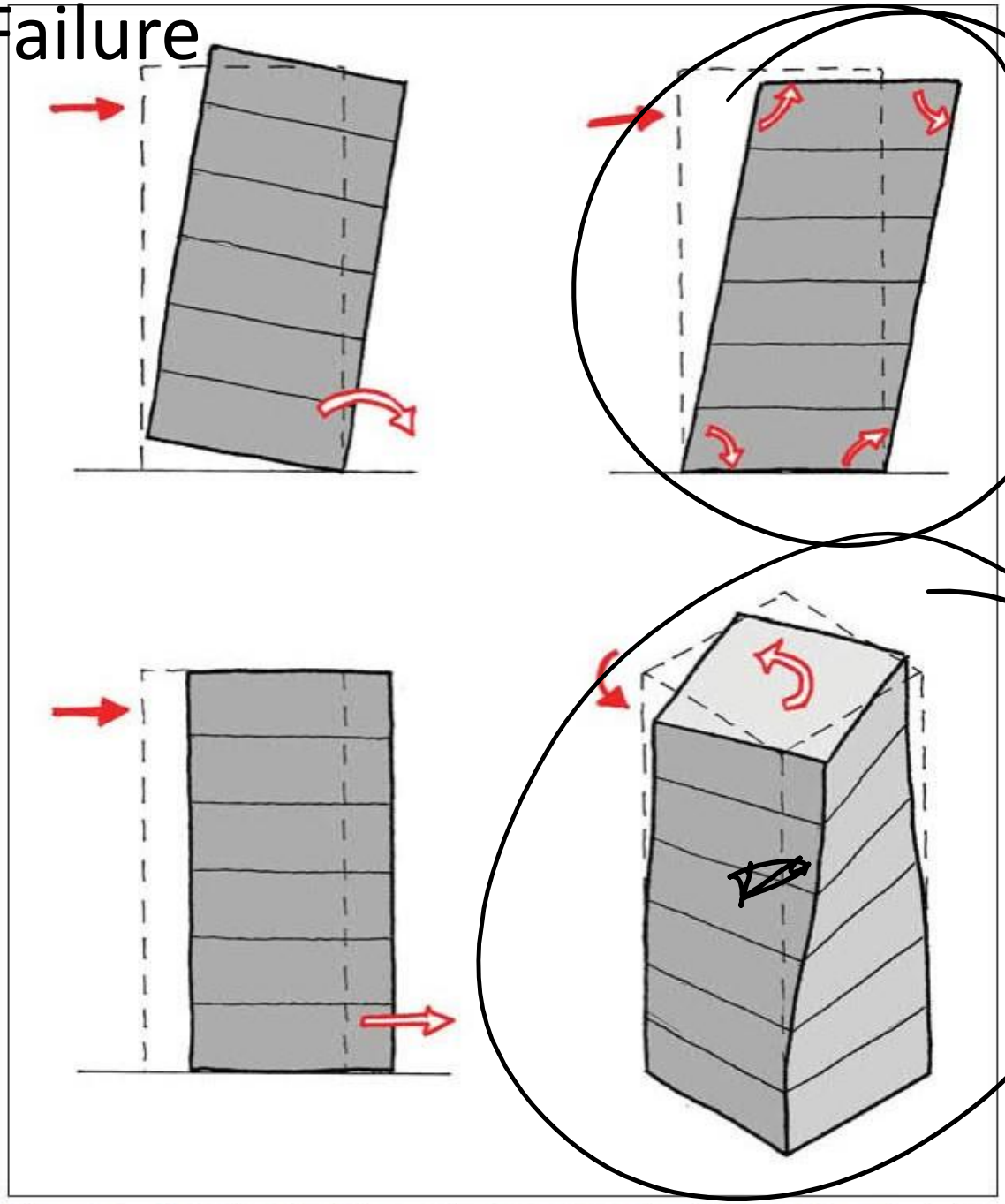
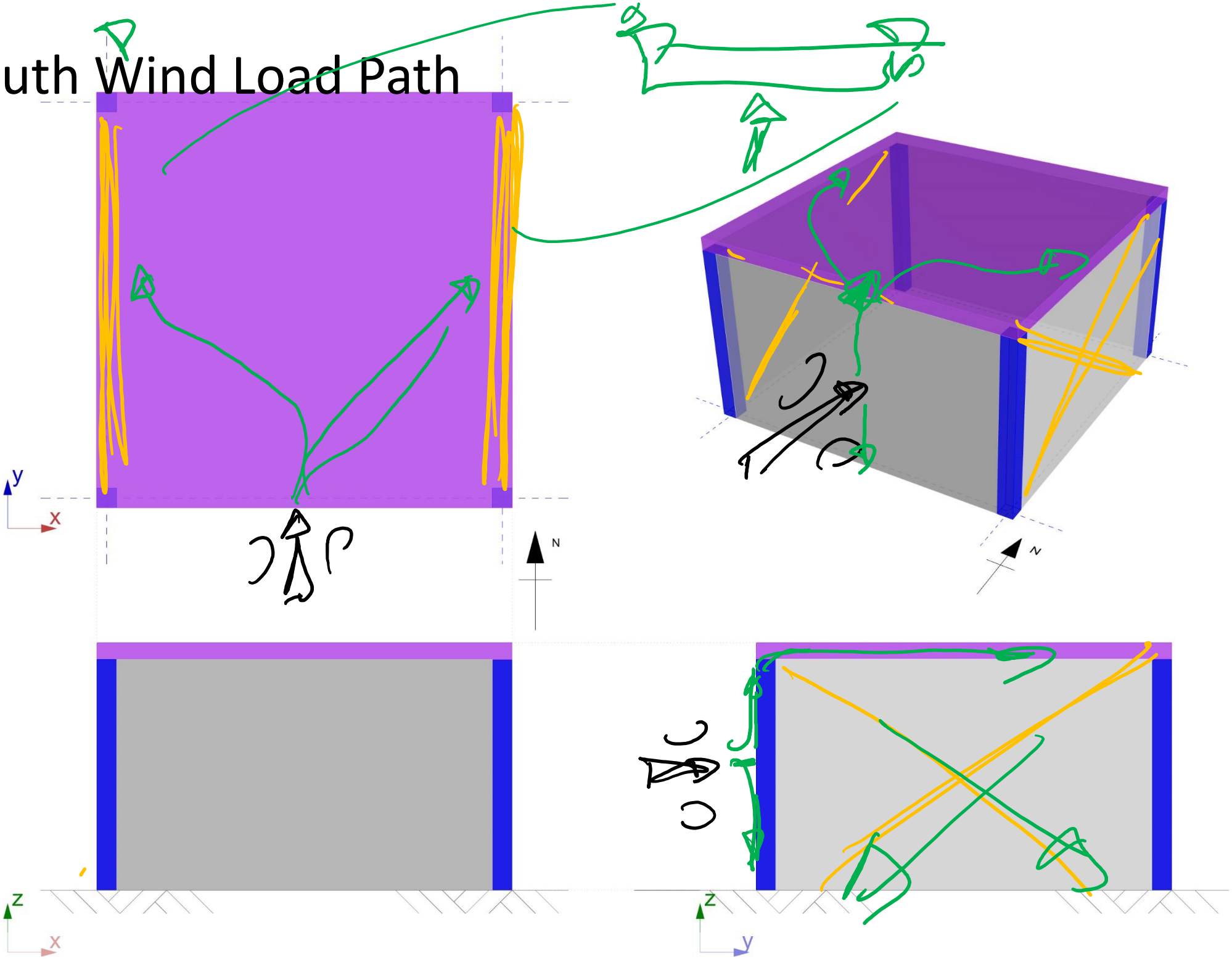


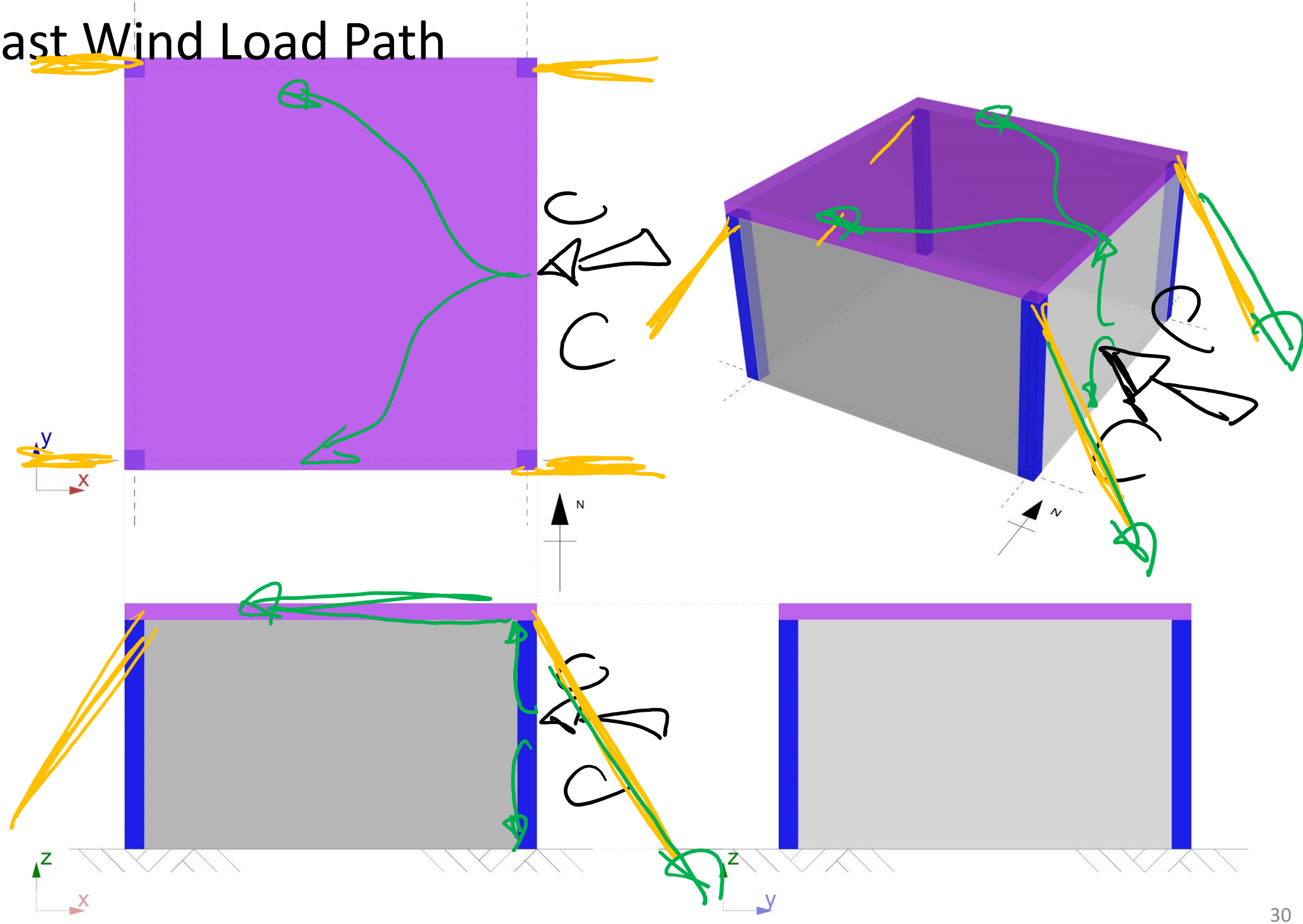
Figure 2.3 Global instability failure mechanisms: overturning, sliding, racking and twisting

Stability of Buildings Part 1 and 2 General Philosophy and Framed Bracing (IStructE) page 4

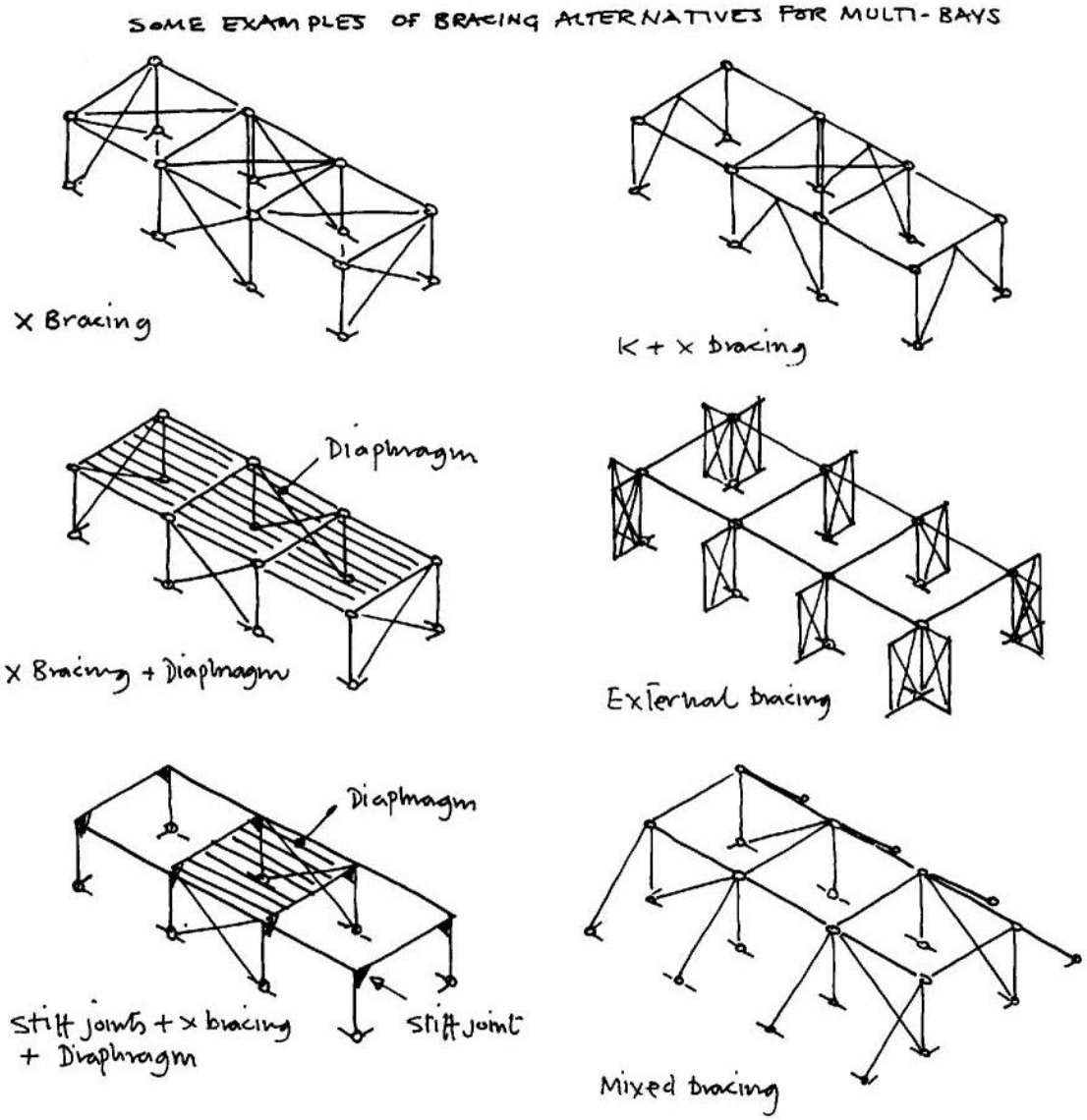
South Wind Load Path



East Wind Load Path



Stability in Two Directions

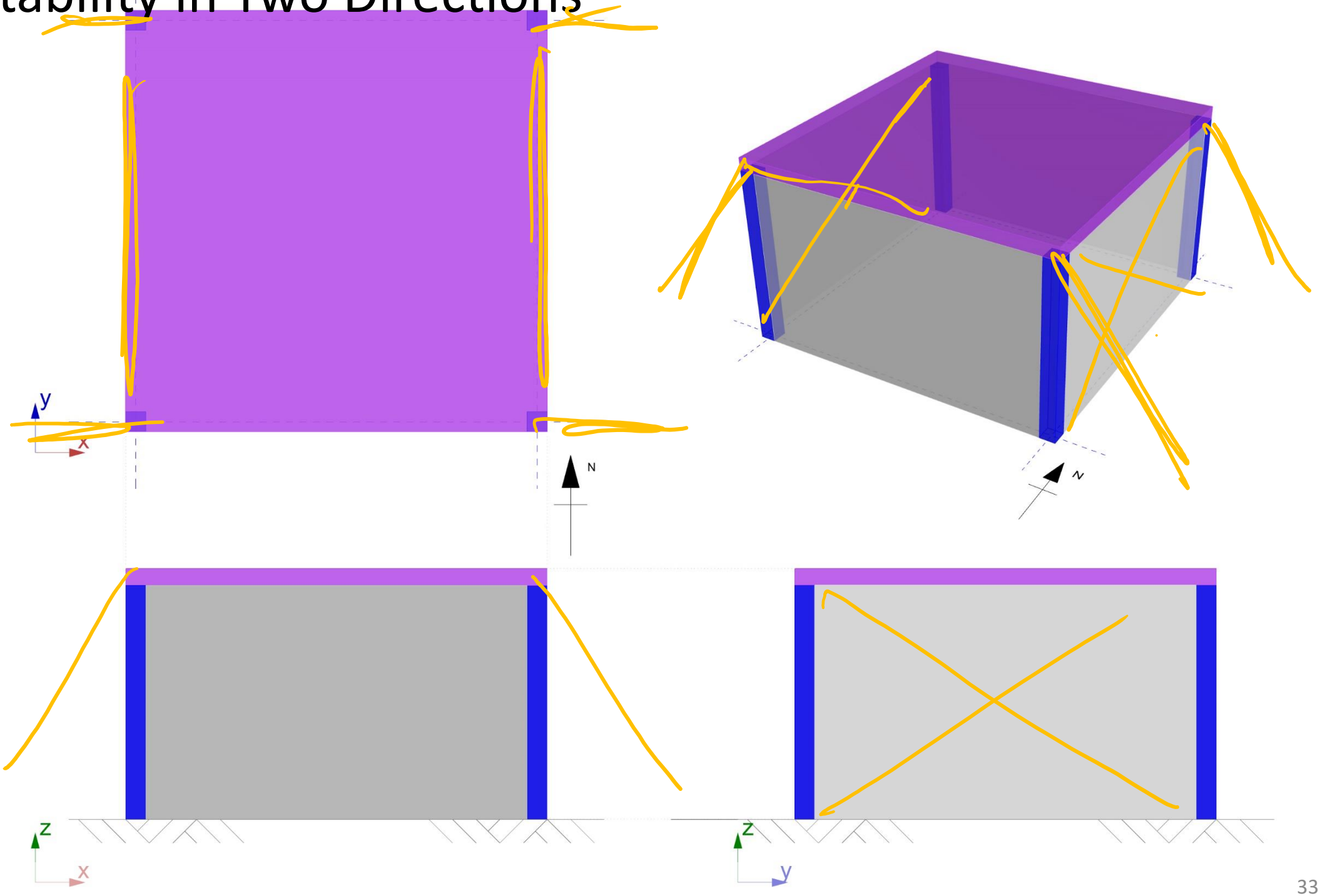


Tony Hunts Structures Notebook (AP) page 63

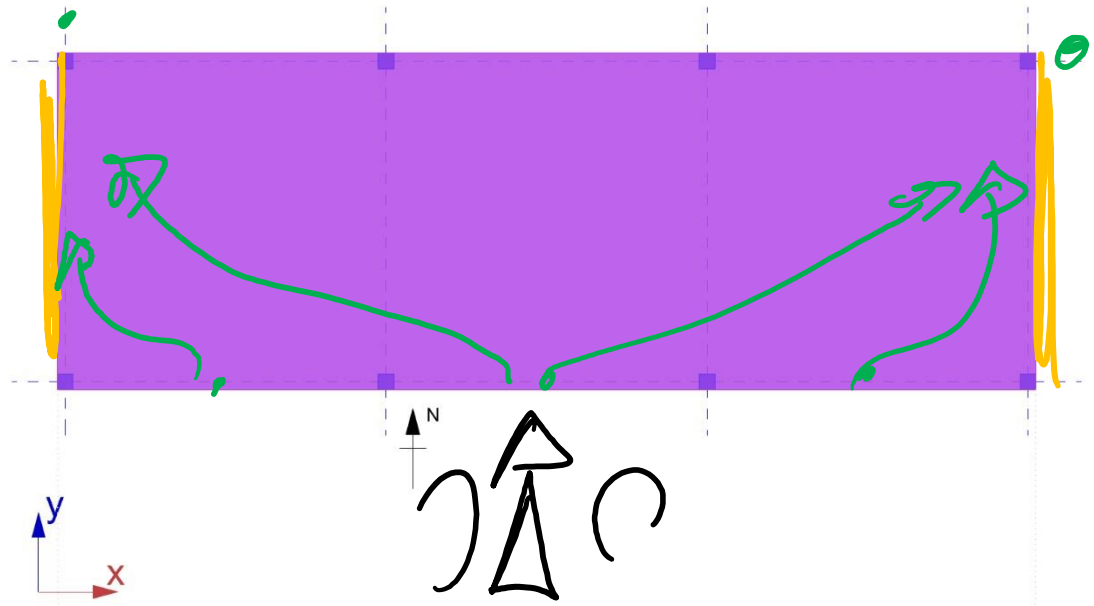
Stability in Two Directions

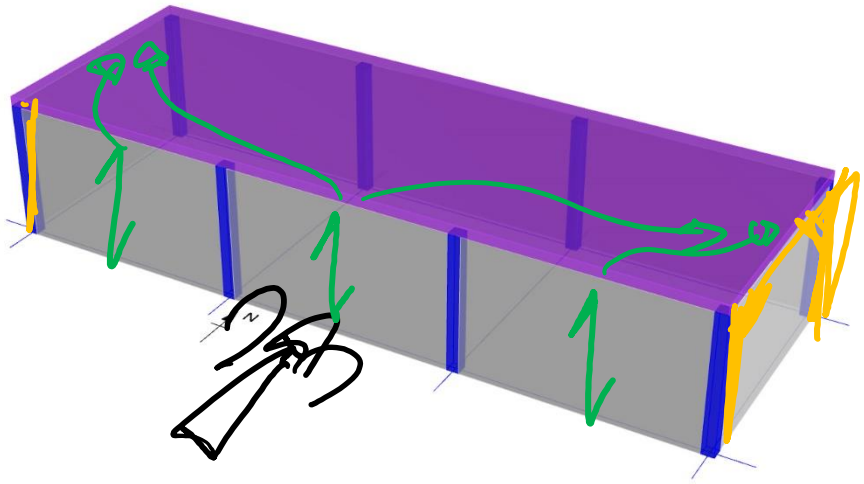
Timber Moment Frame and Braced Frame, Frame Structure, Lighthouse in England 2018 Conor Moris with engineersHRW (Photo Ciaran Malik)

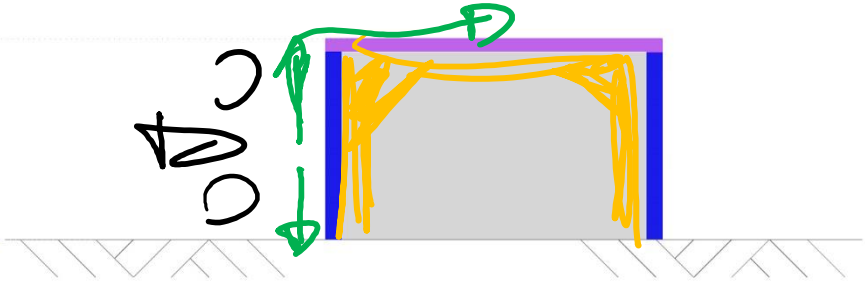
Stability in Two Directions



South Wind Load Path, Perimeter System



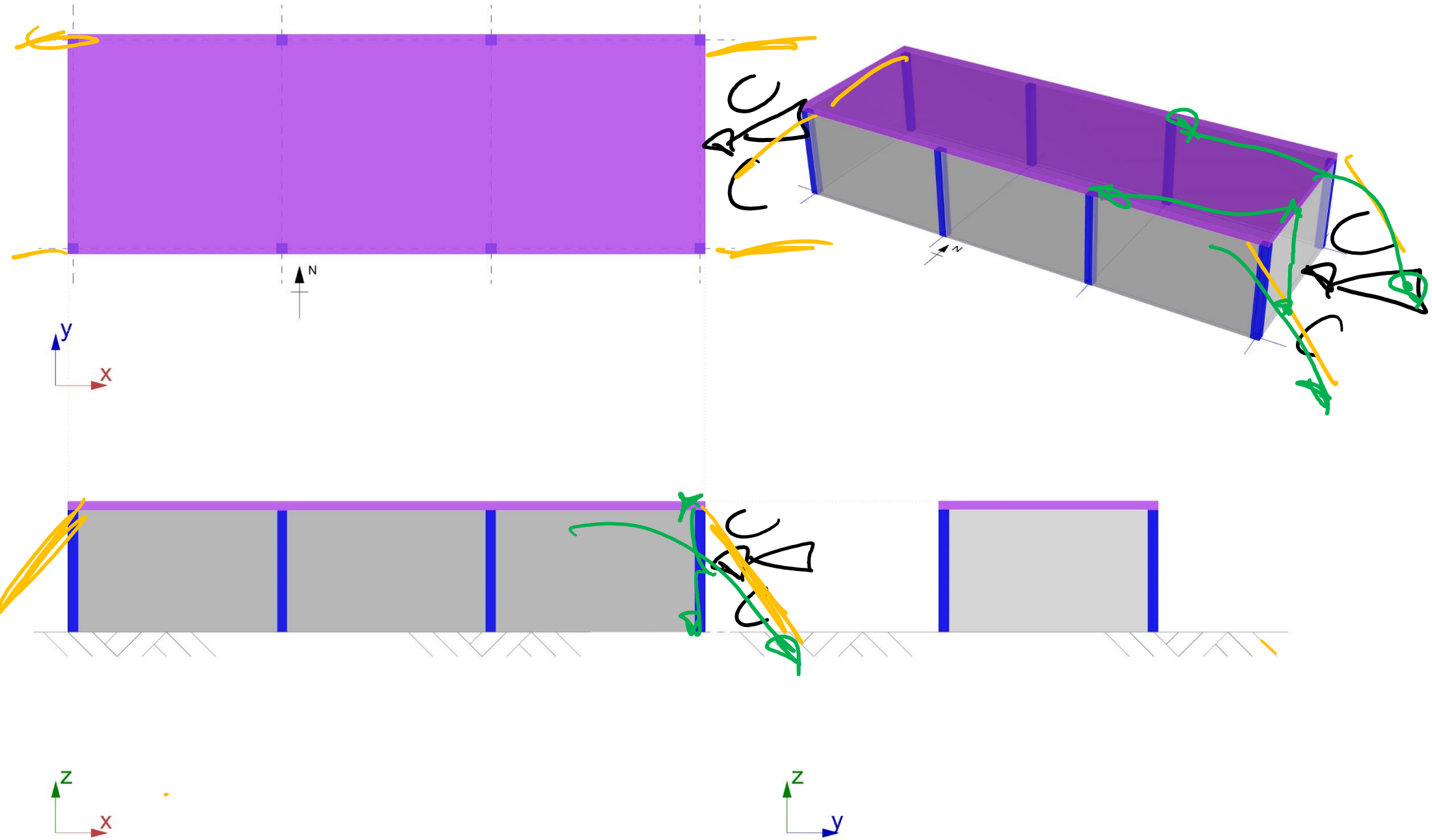




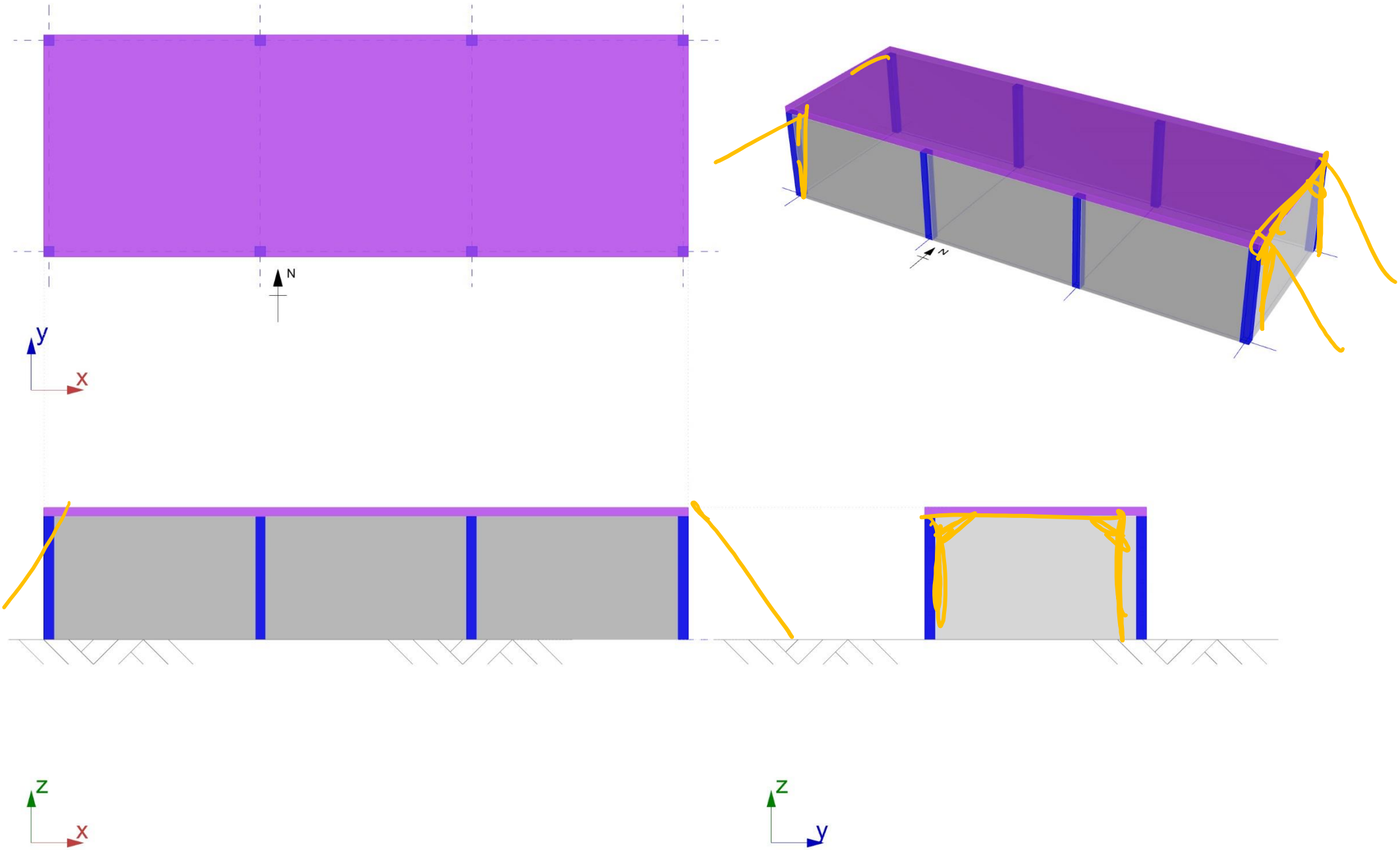
z
x

z
y

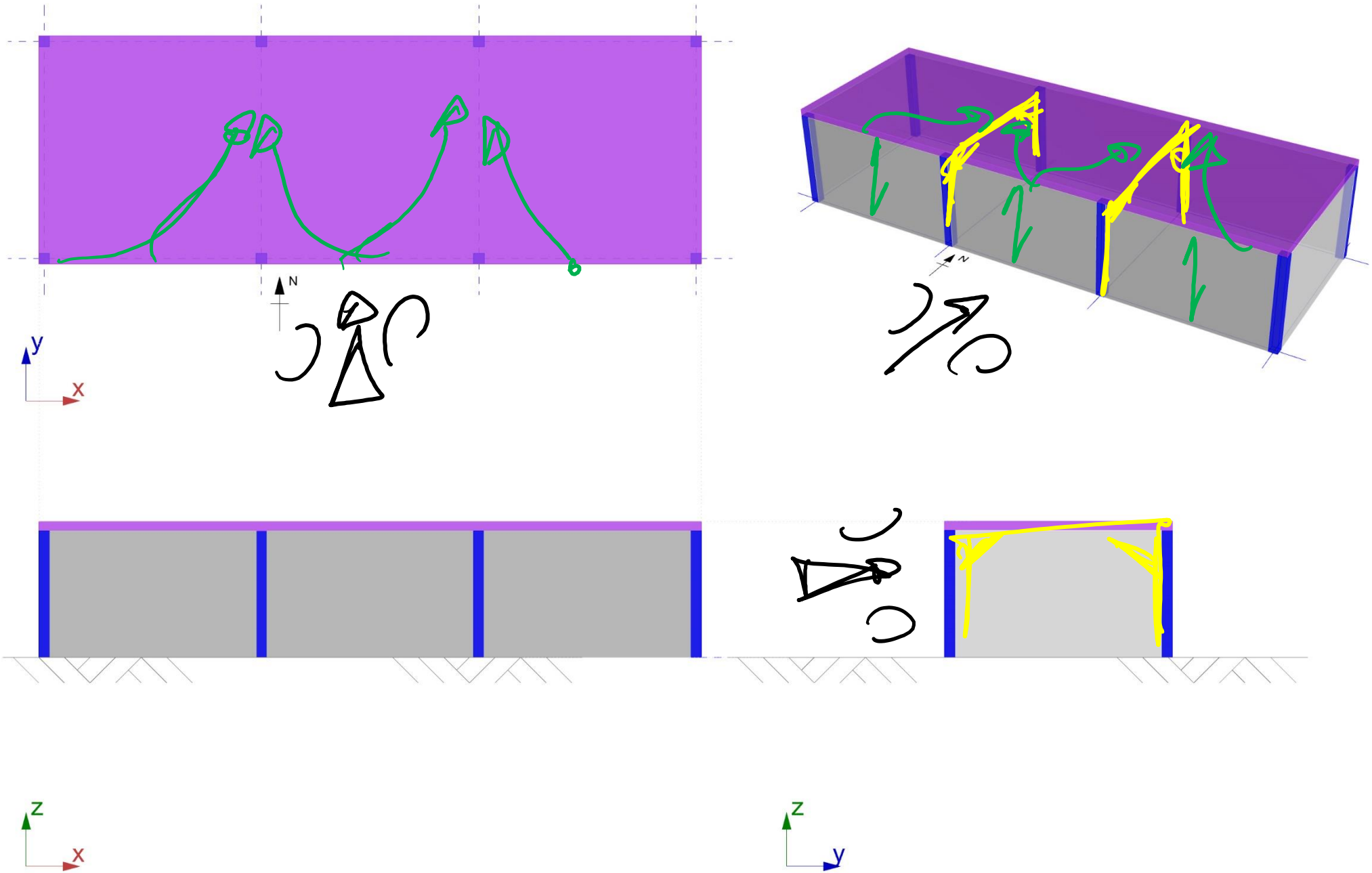
East Wind Load Path



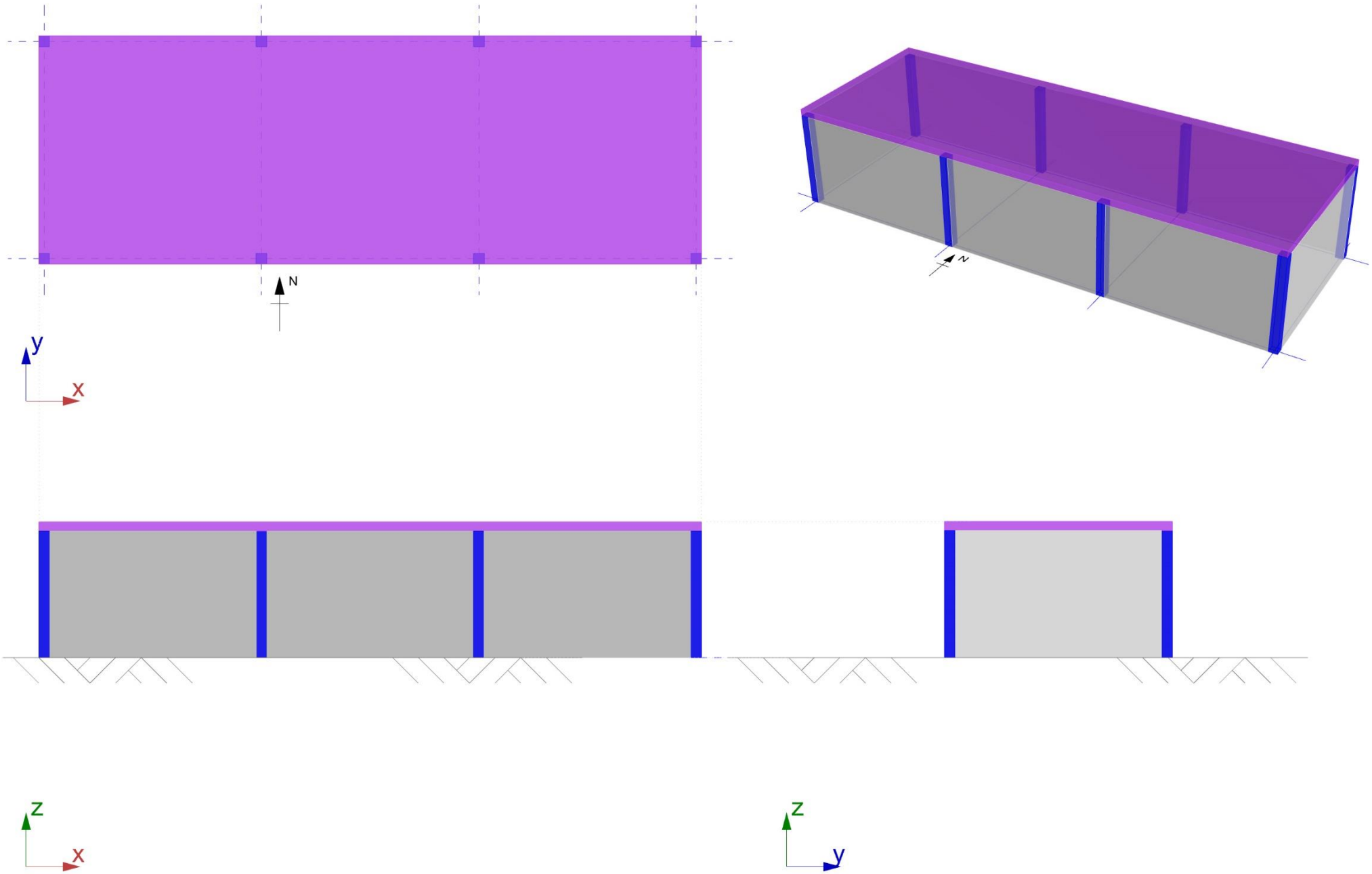
Stability in Two Directions



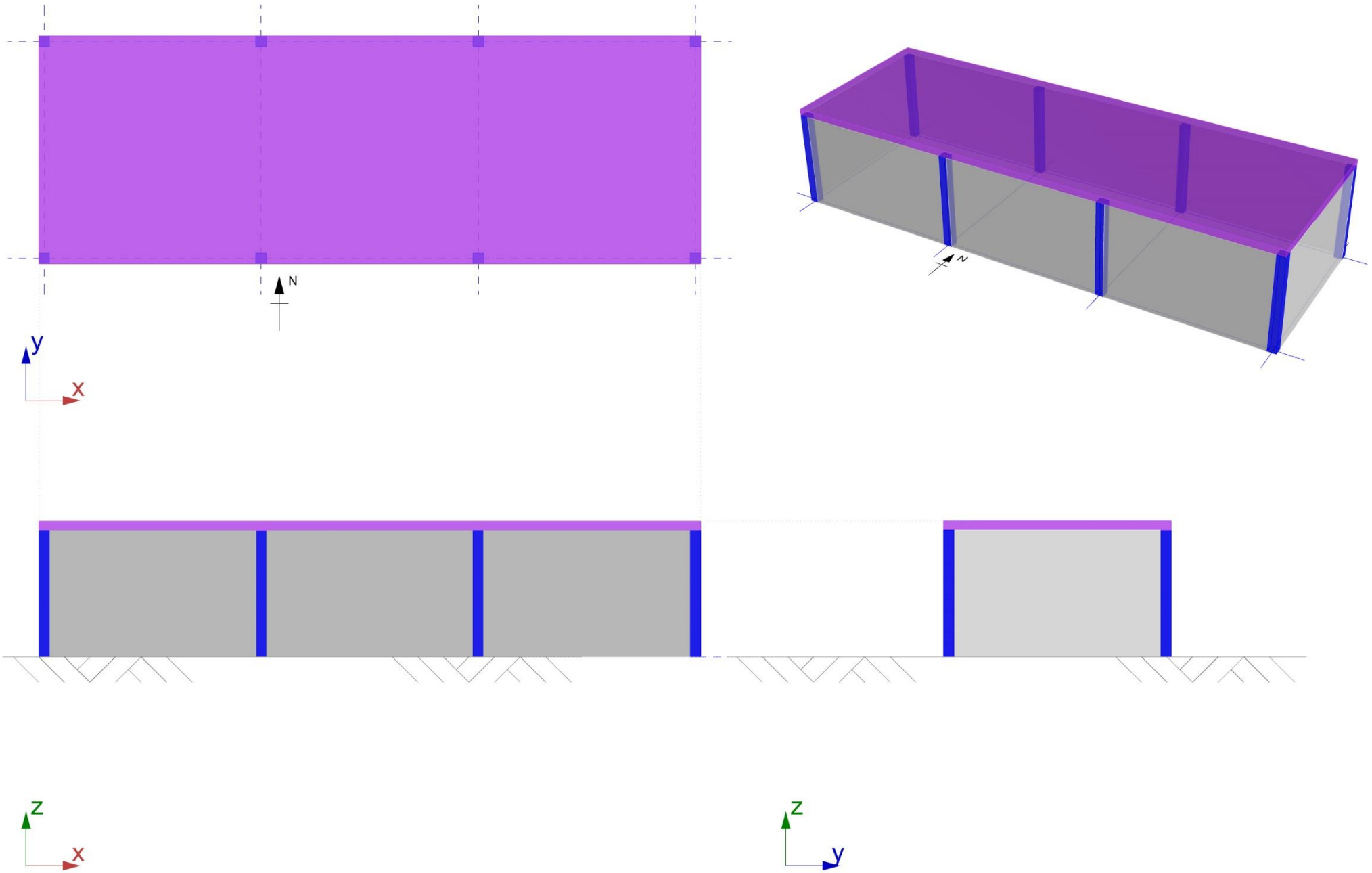
South Wind Load Path, Internal System



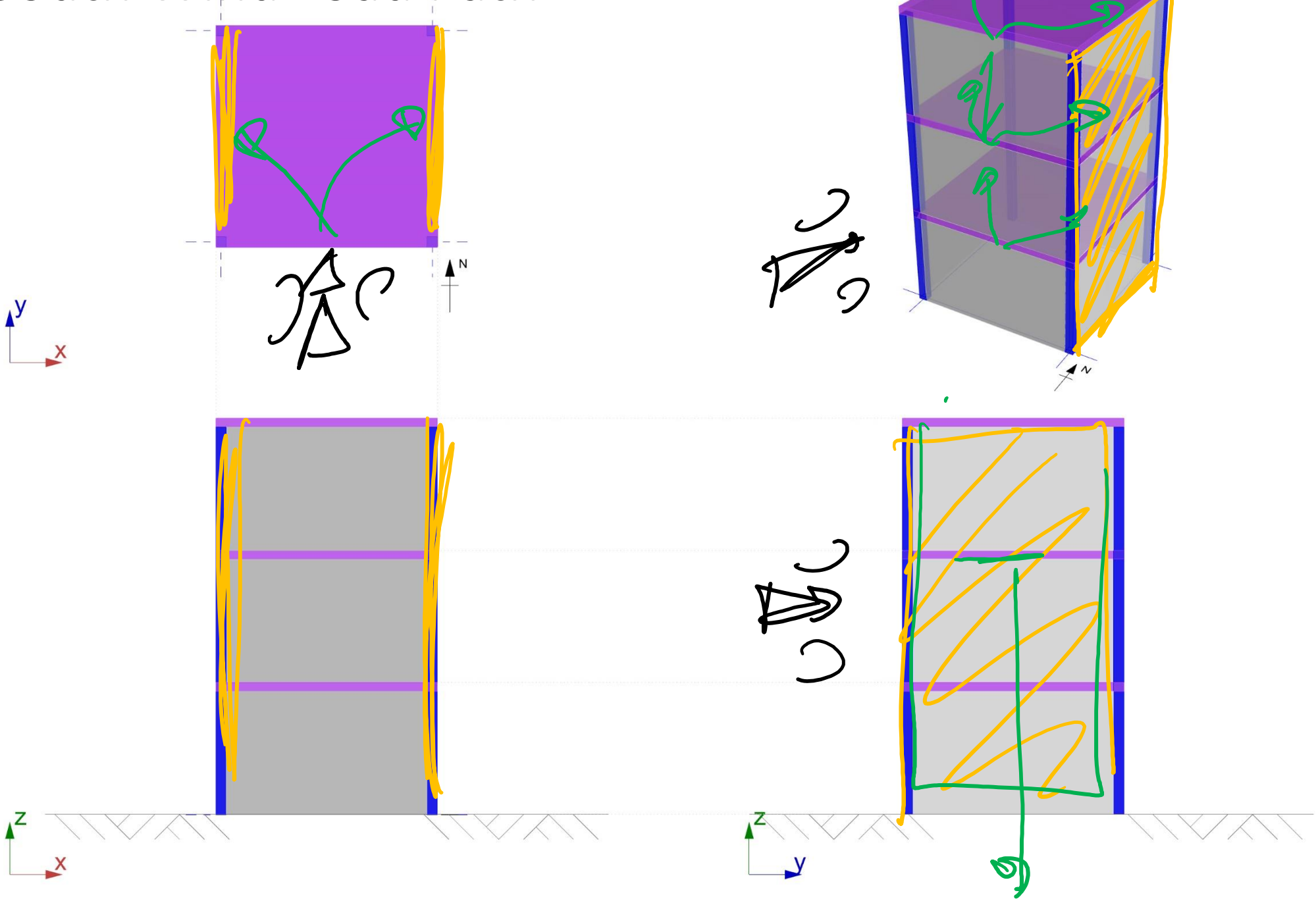
East Wind Load Path



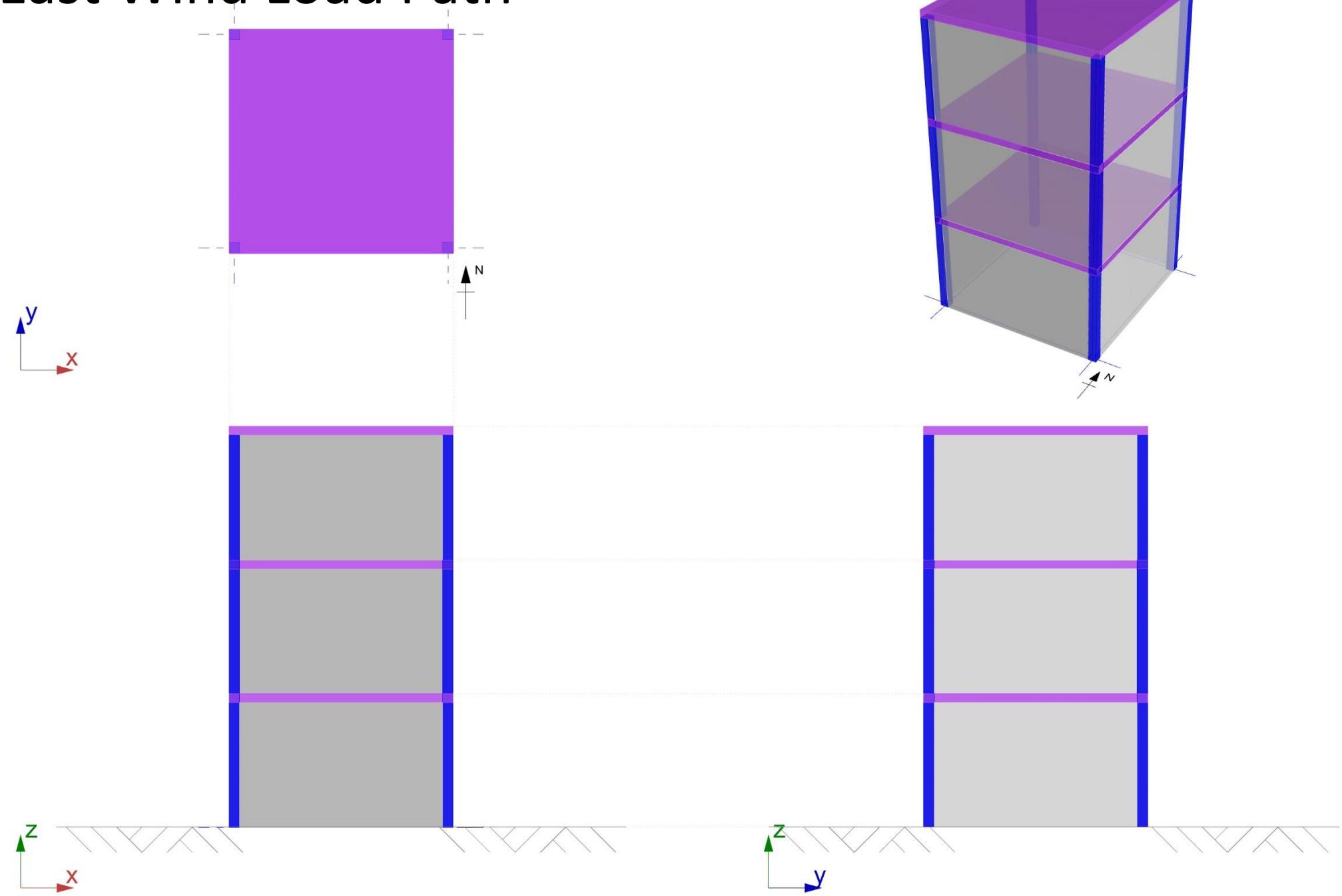
Stability in Two Directions



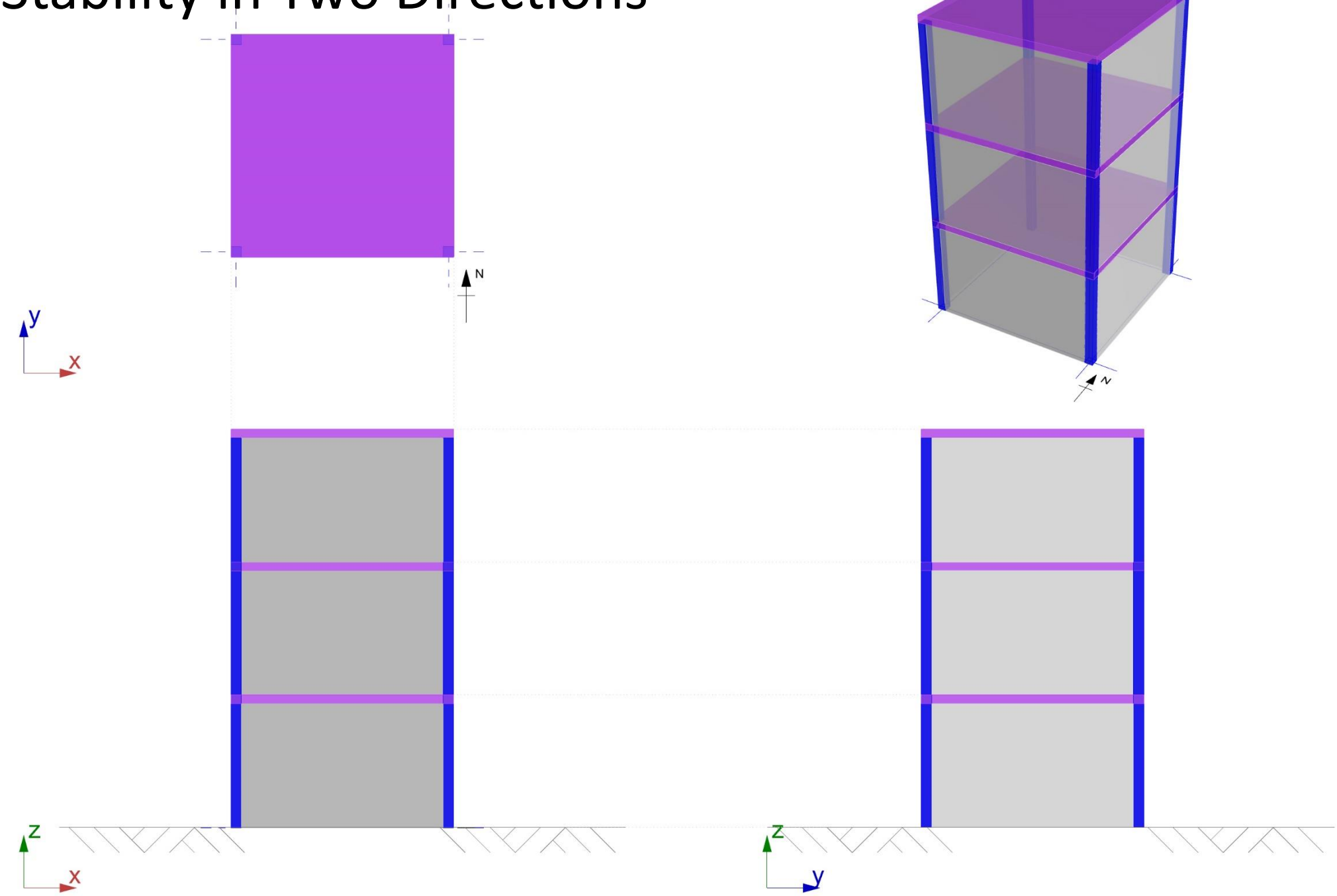
South Wind Load Path



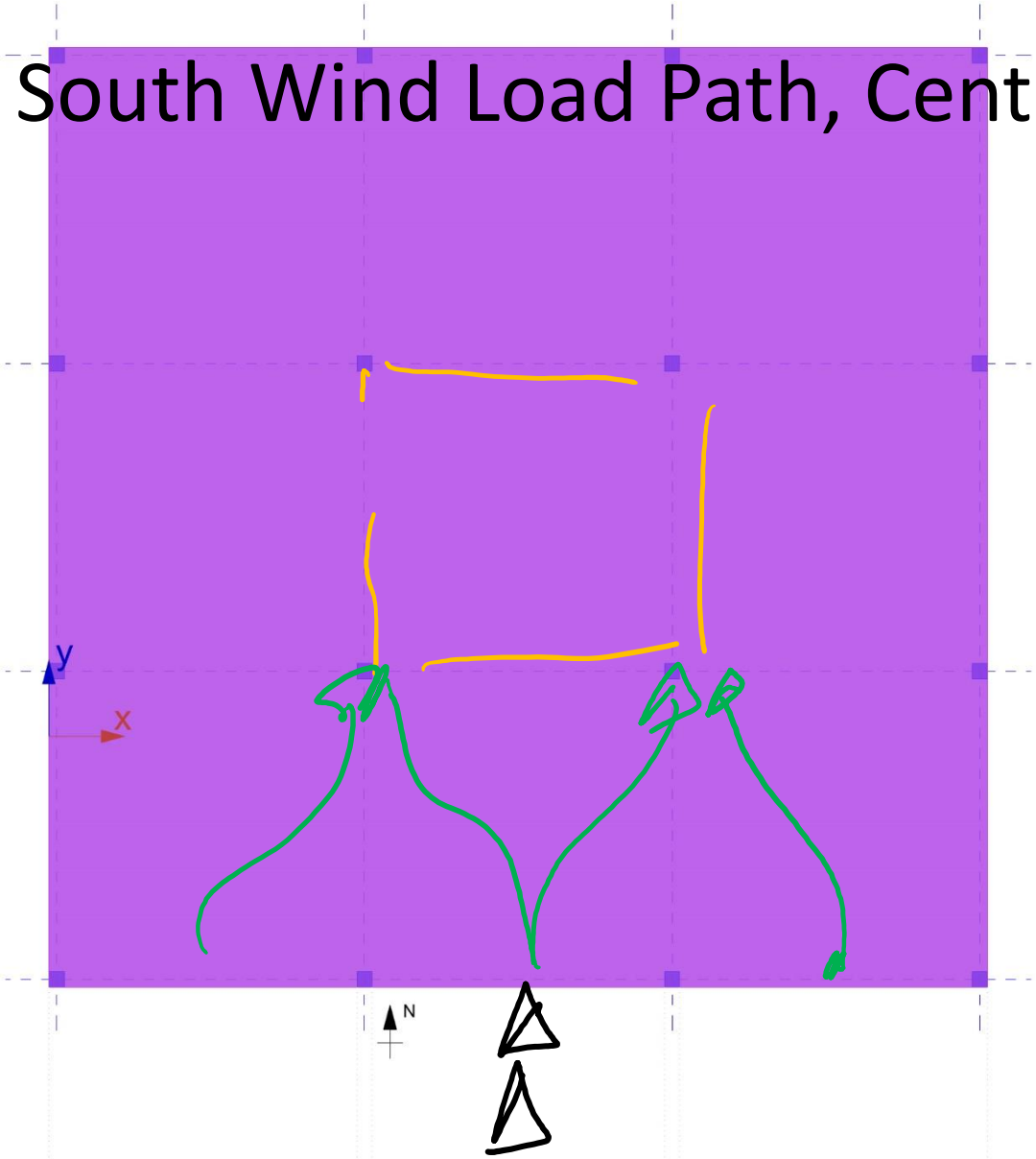
East Wind Load Path

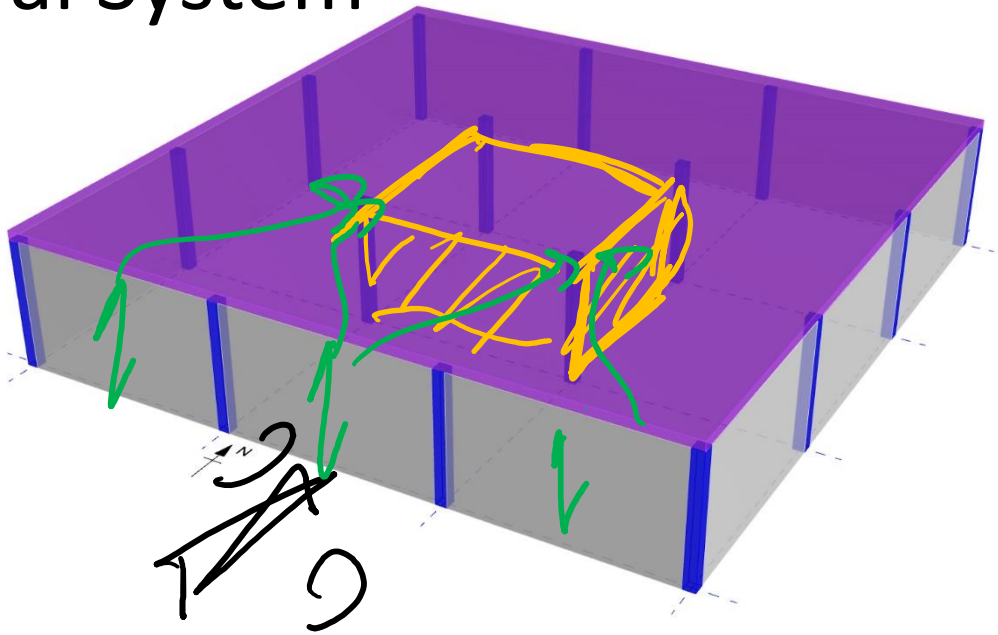


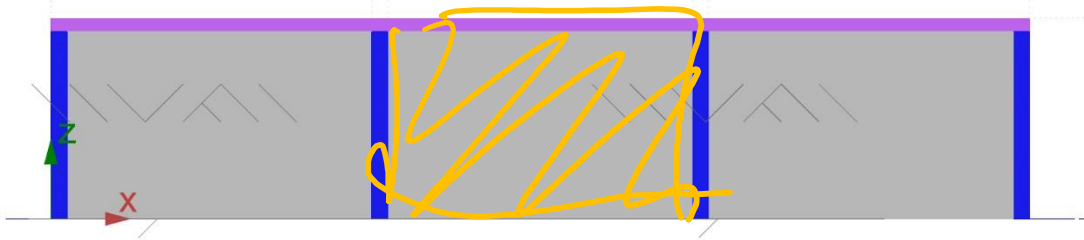
Stability in Two Directions

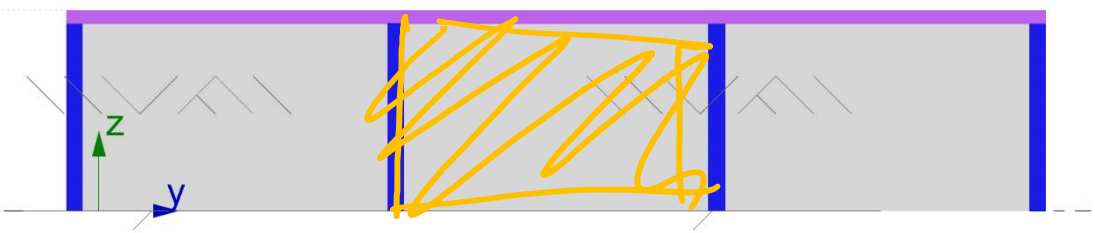


South Wind Load Path, Central System

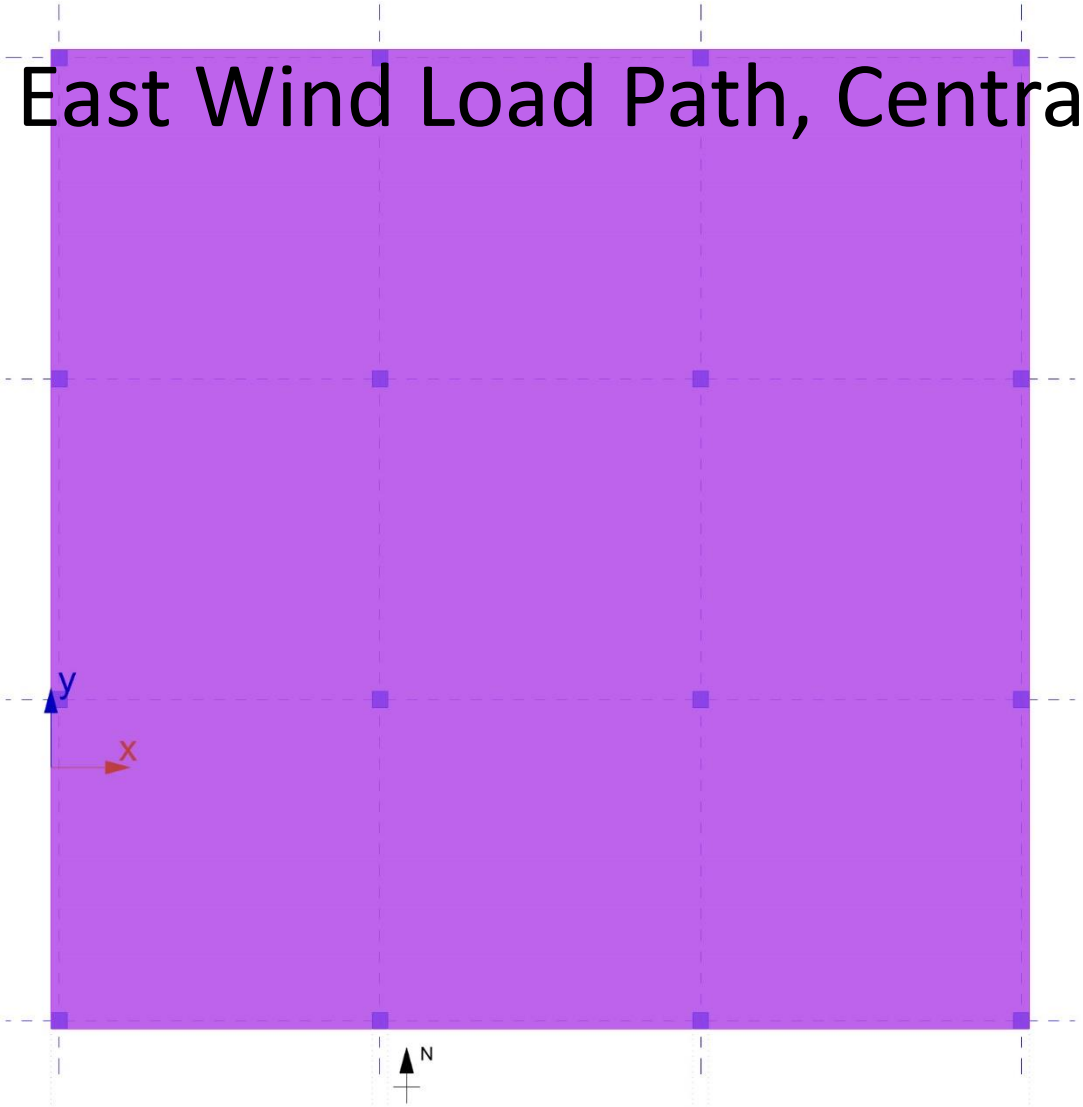


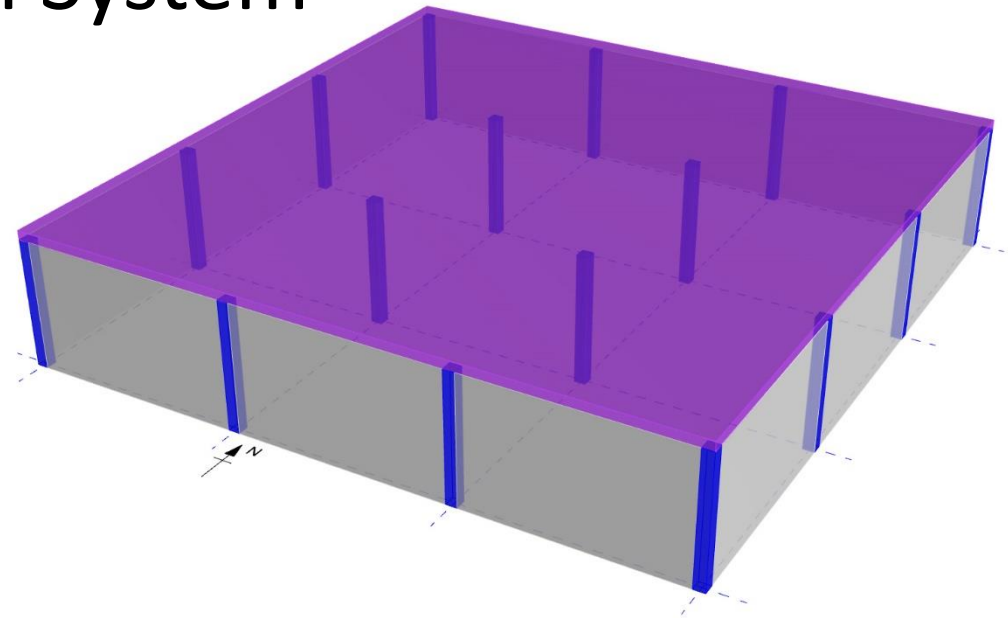




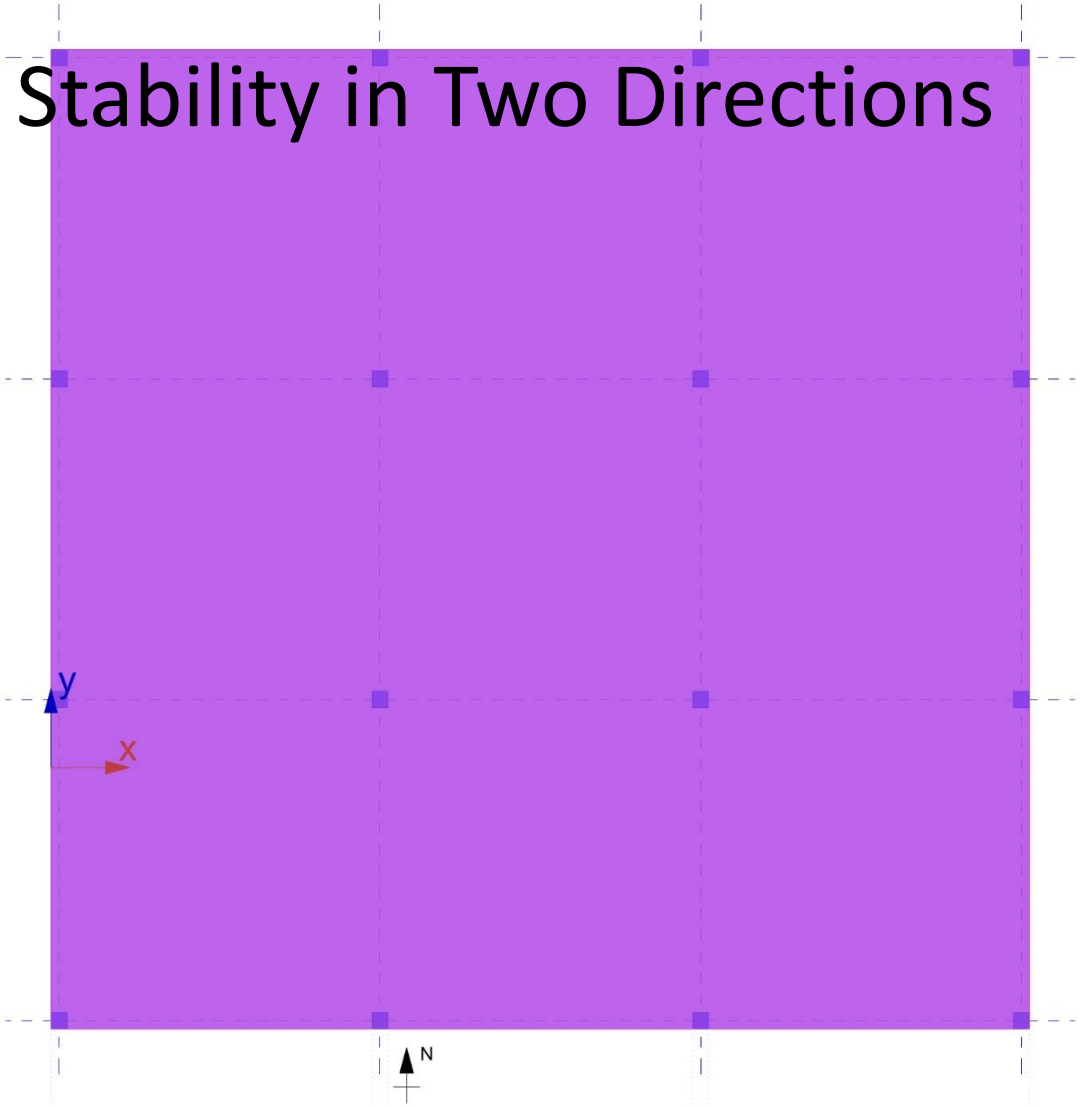


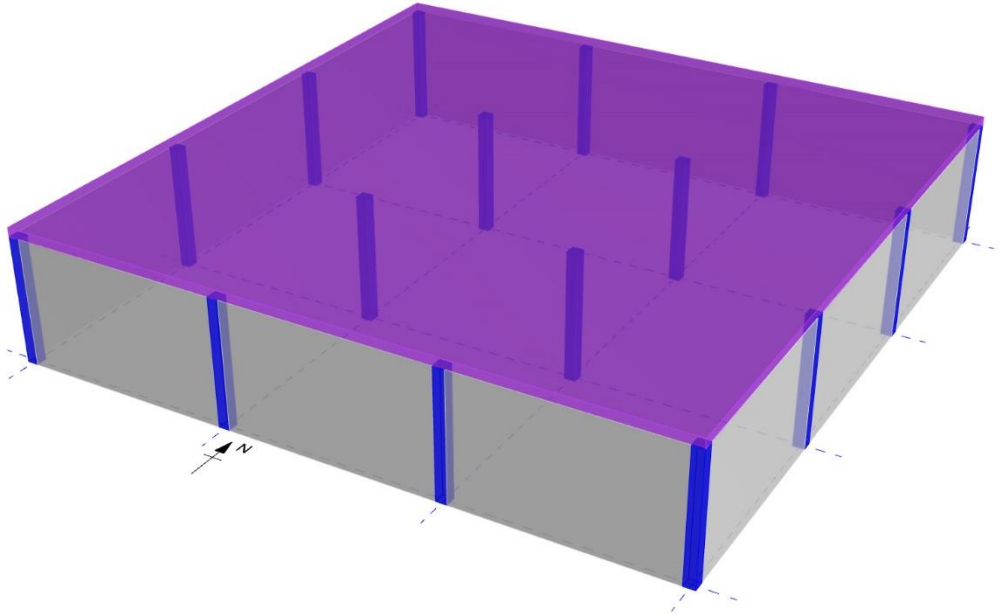
East Wind Load Path, Central System



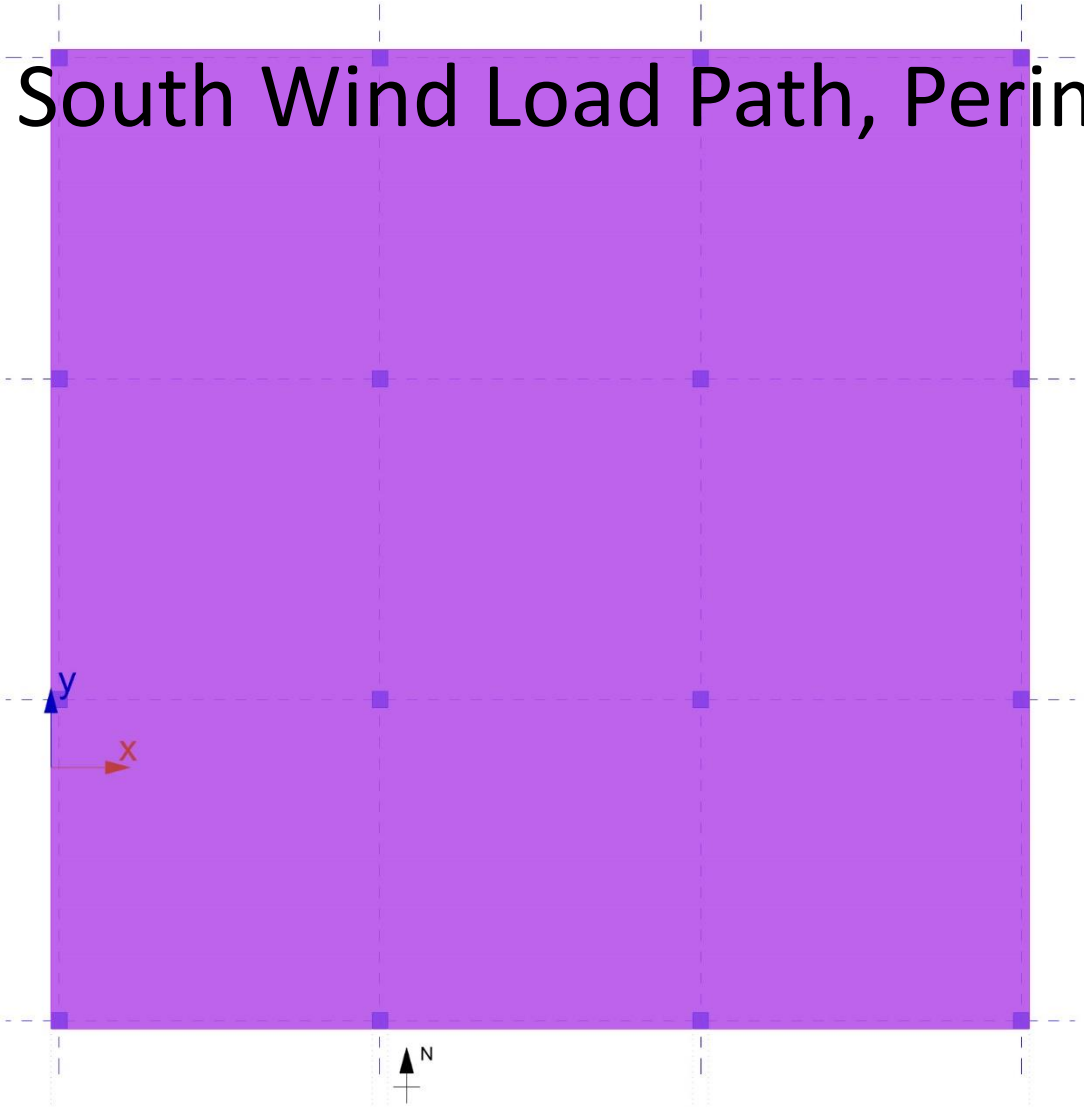


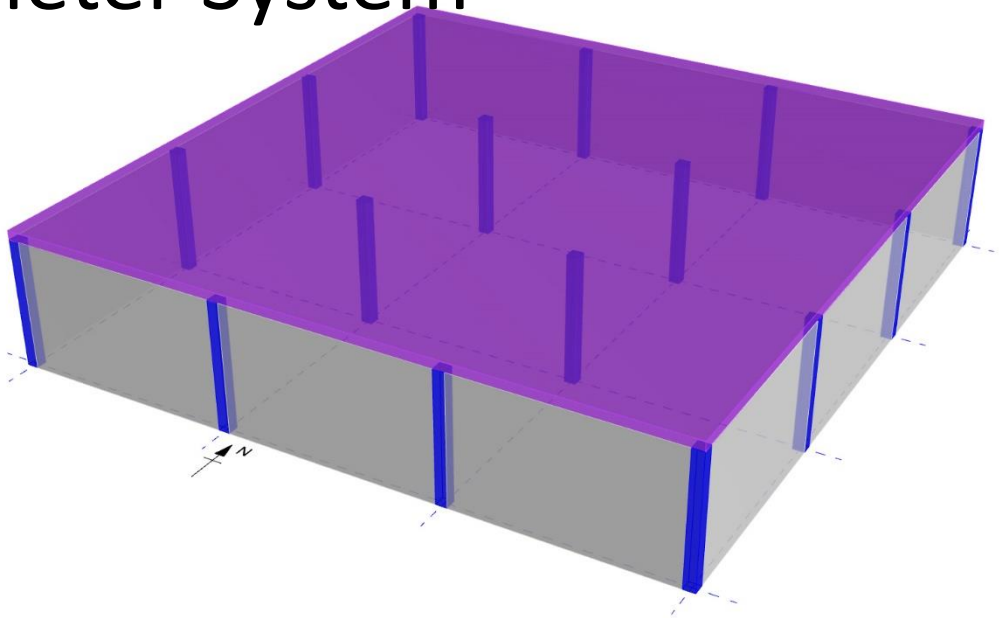
Stability in Two Directions



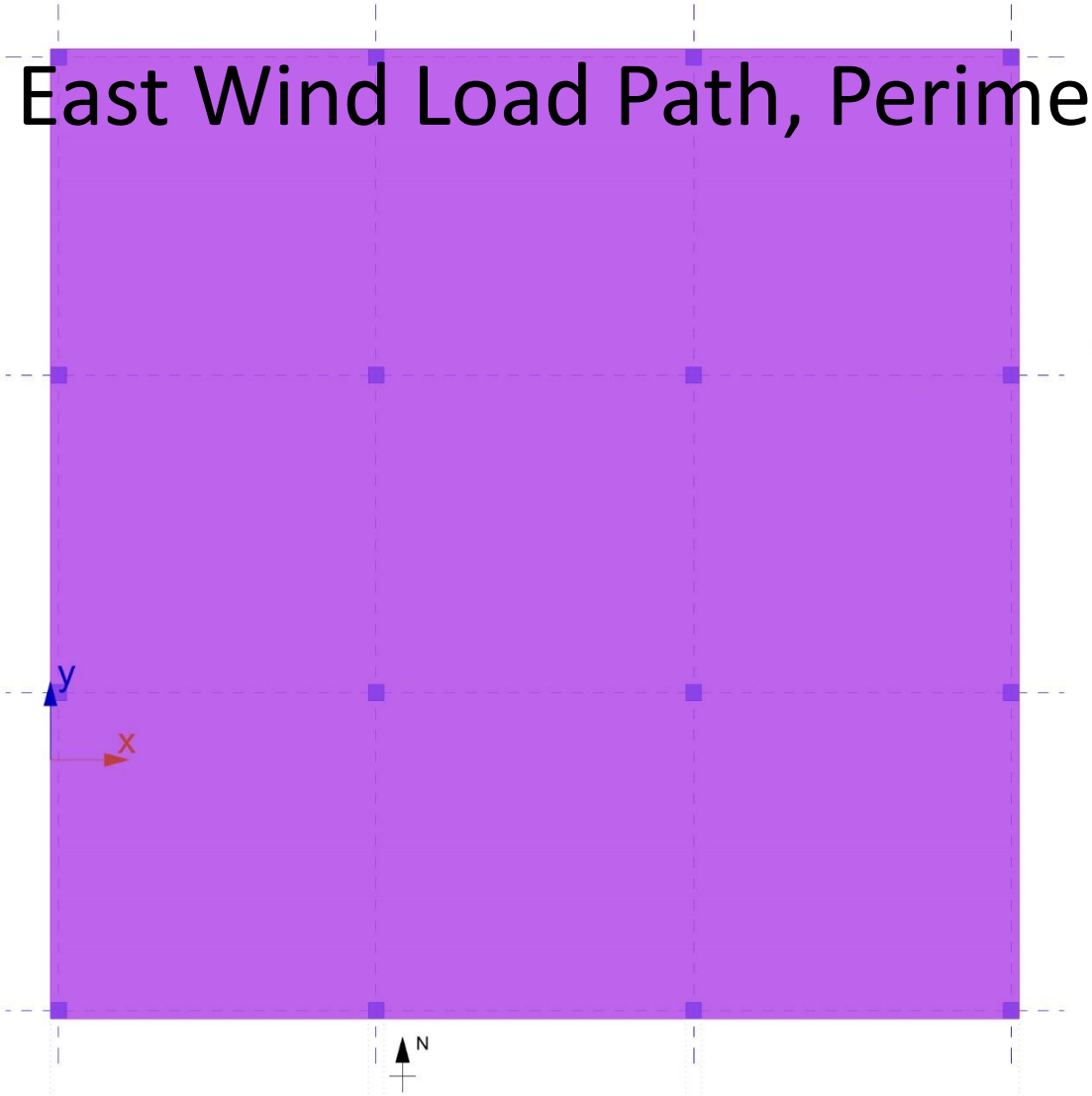


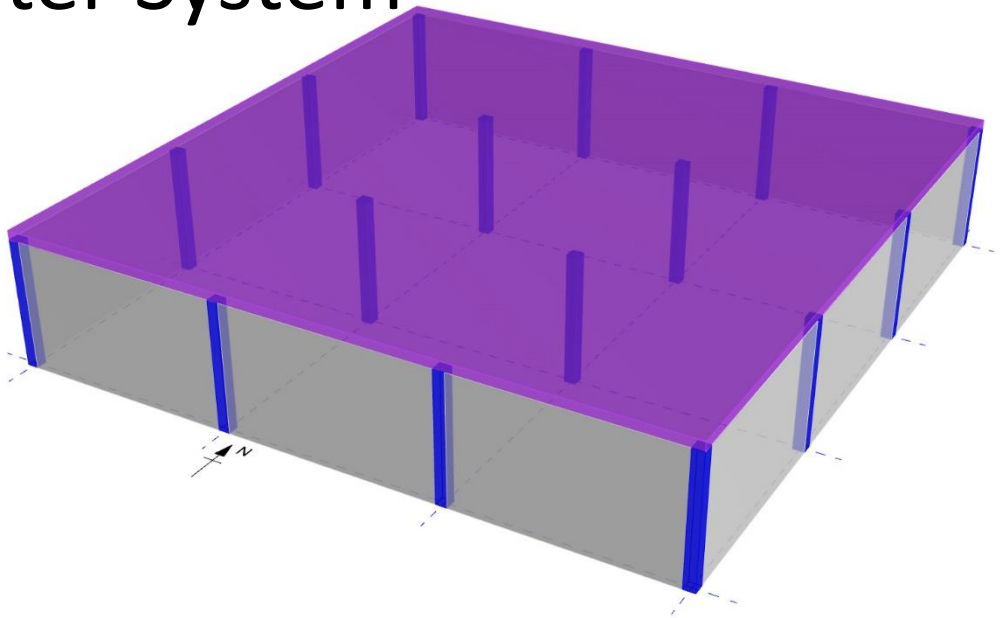
South Wind Load Path, Perimeter System



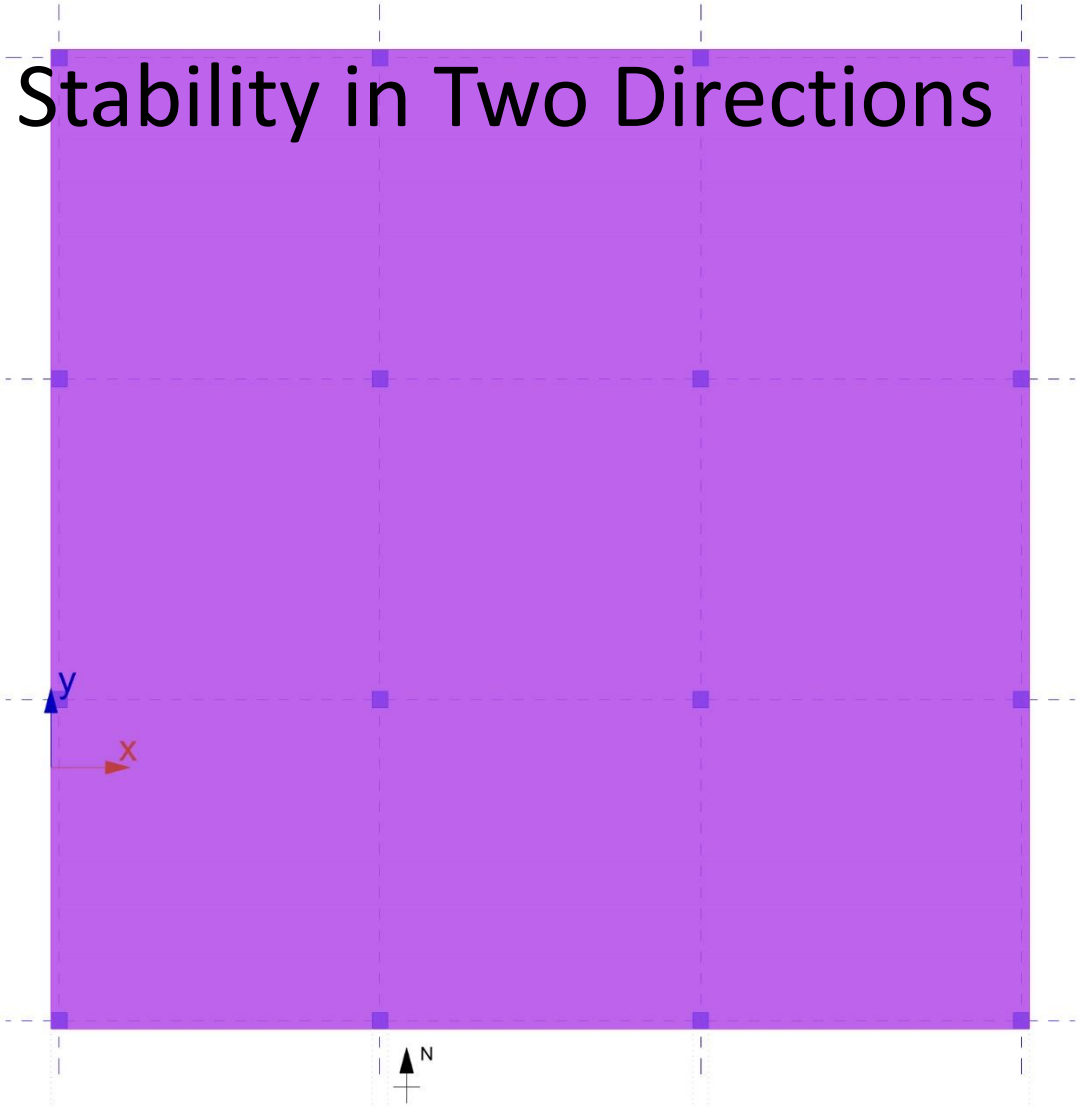


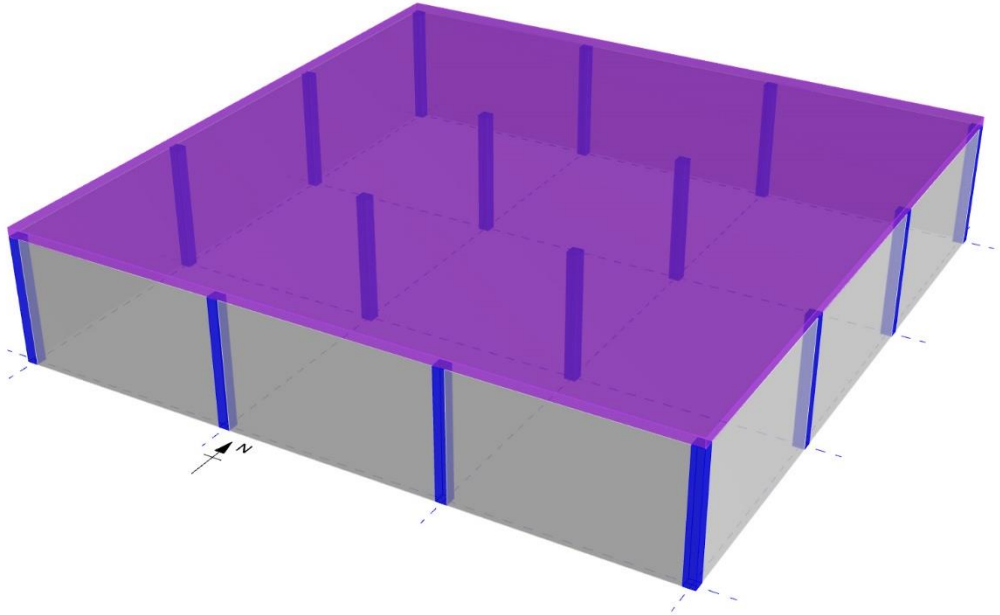
East Wind Load Path, Perimeter System



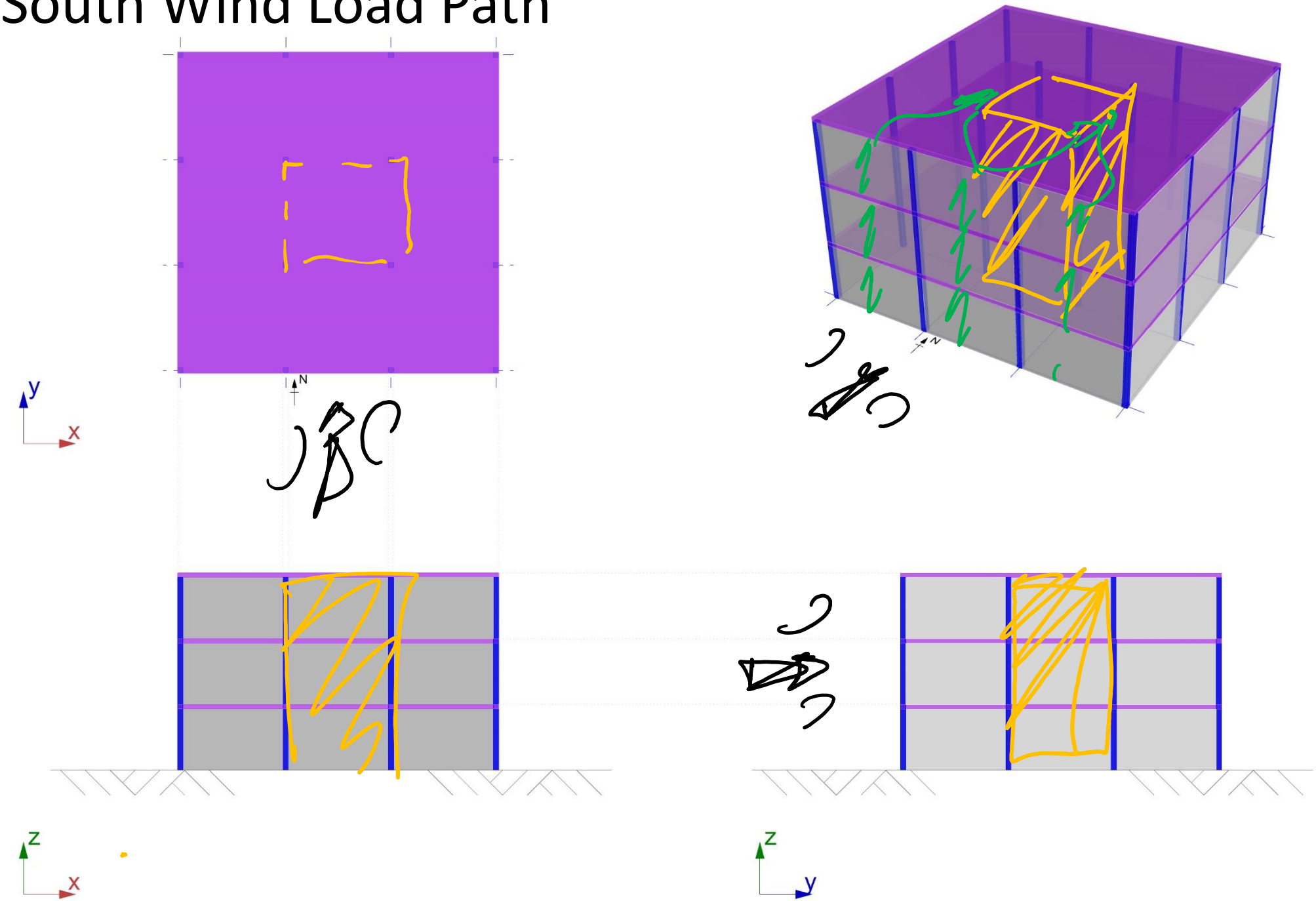


Stability in Two Directions

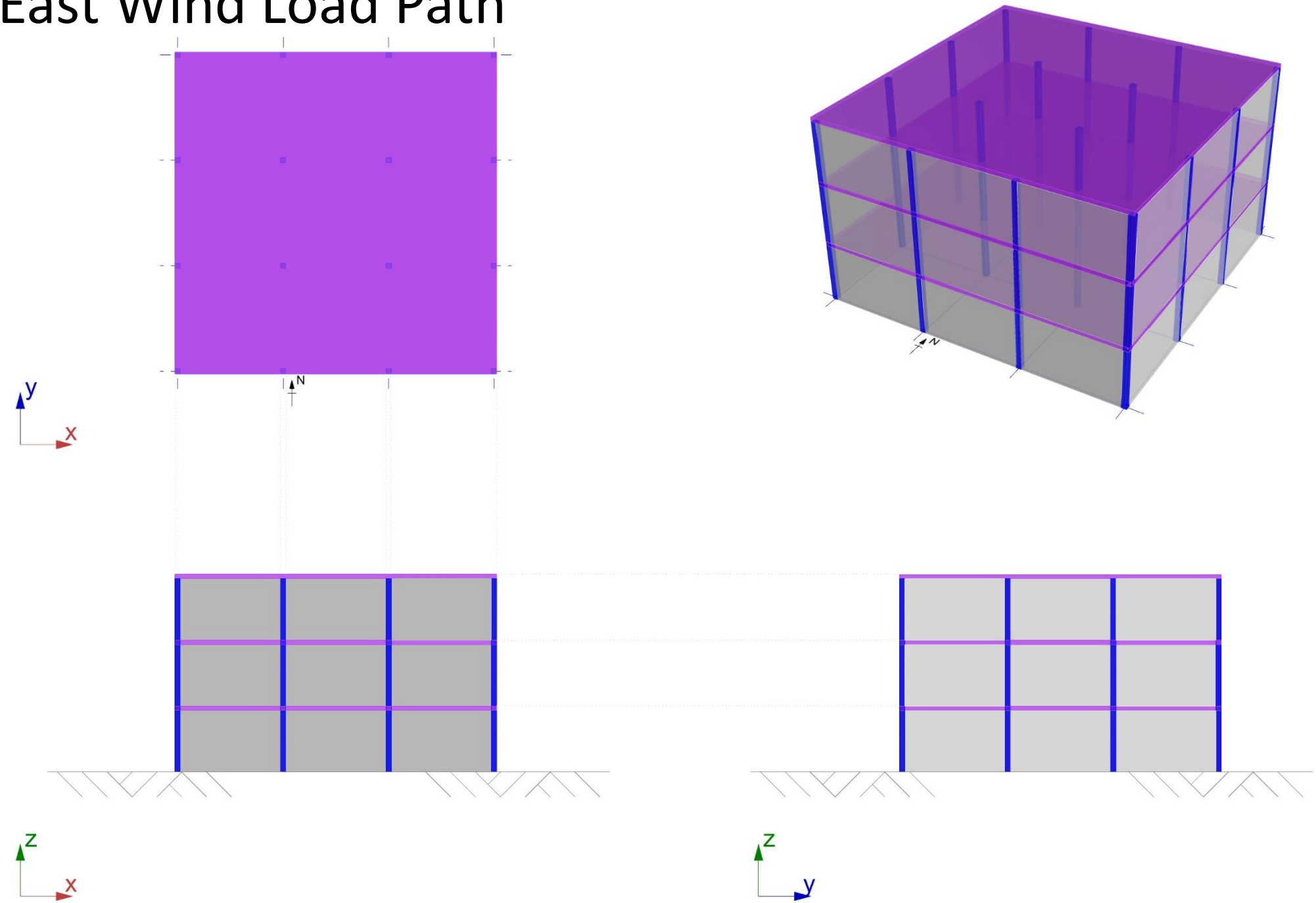




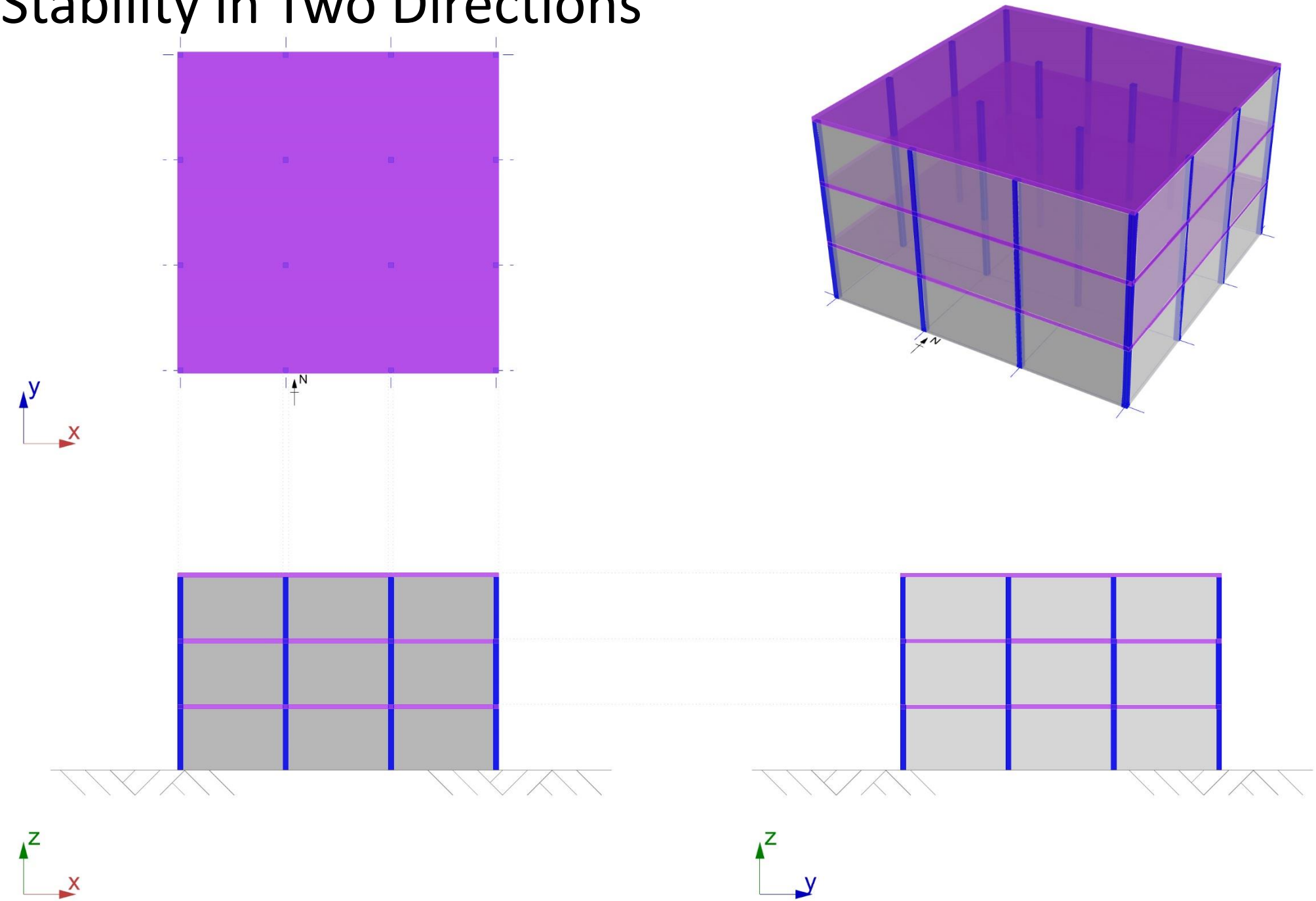
South Wind Load Path



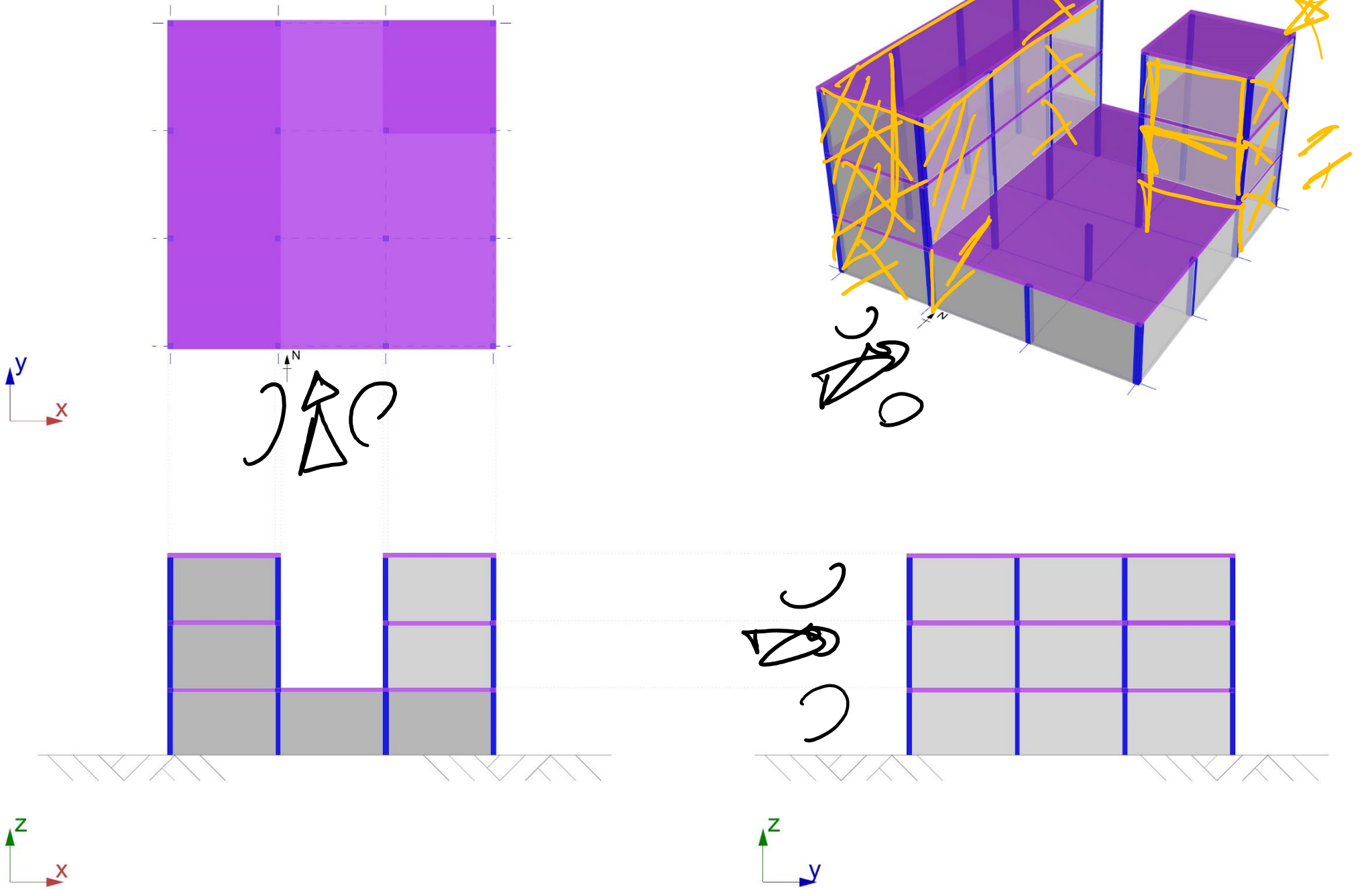
East Wind Load Path



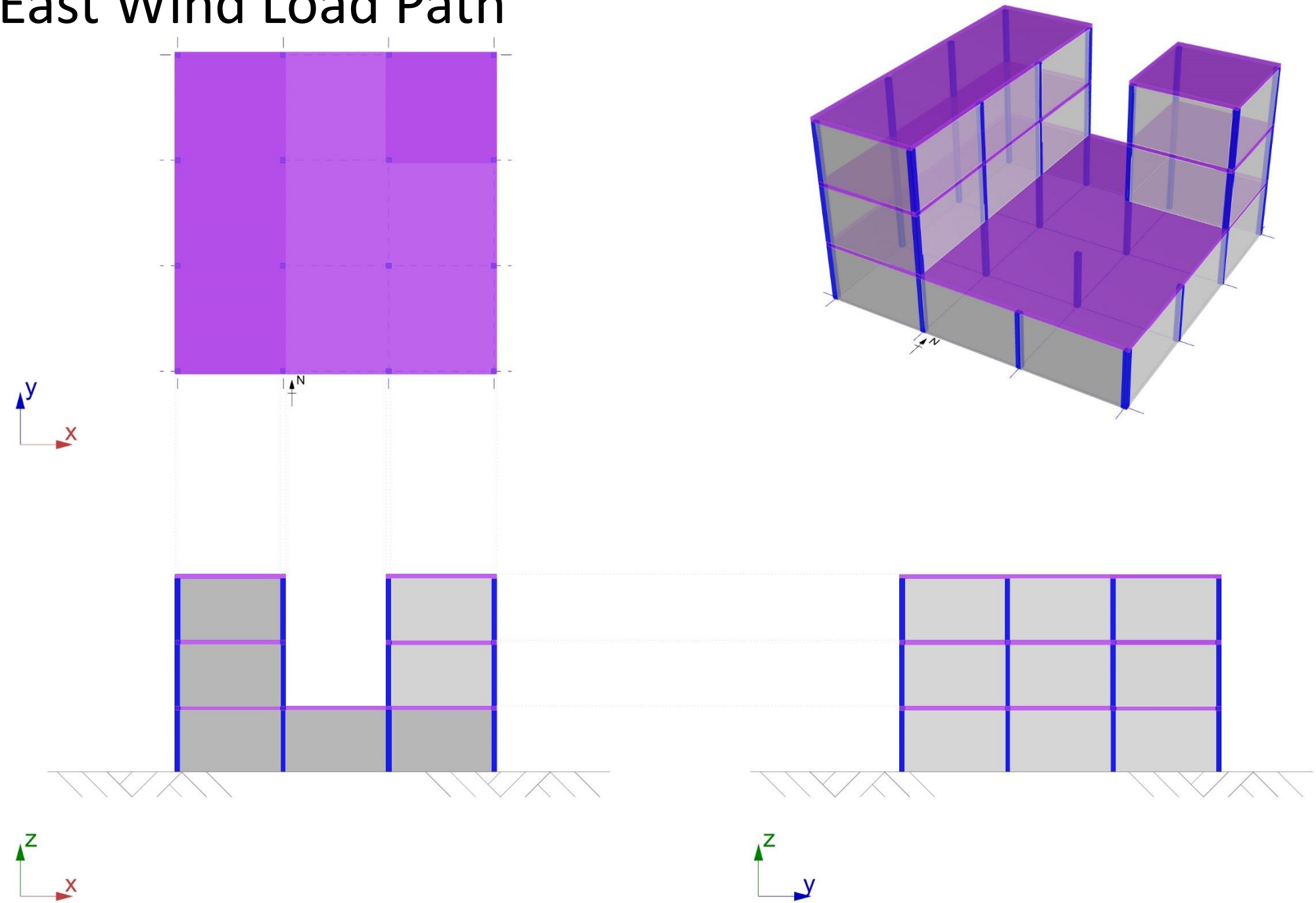
Stability in Two Directions



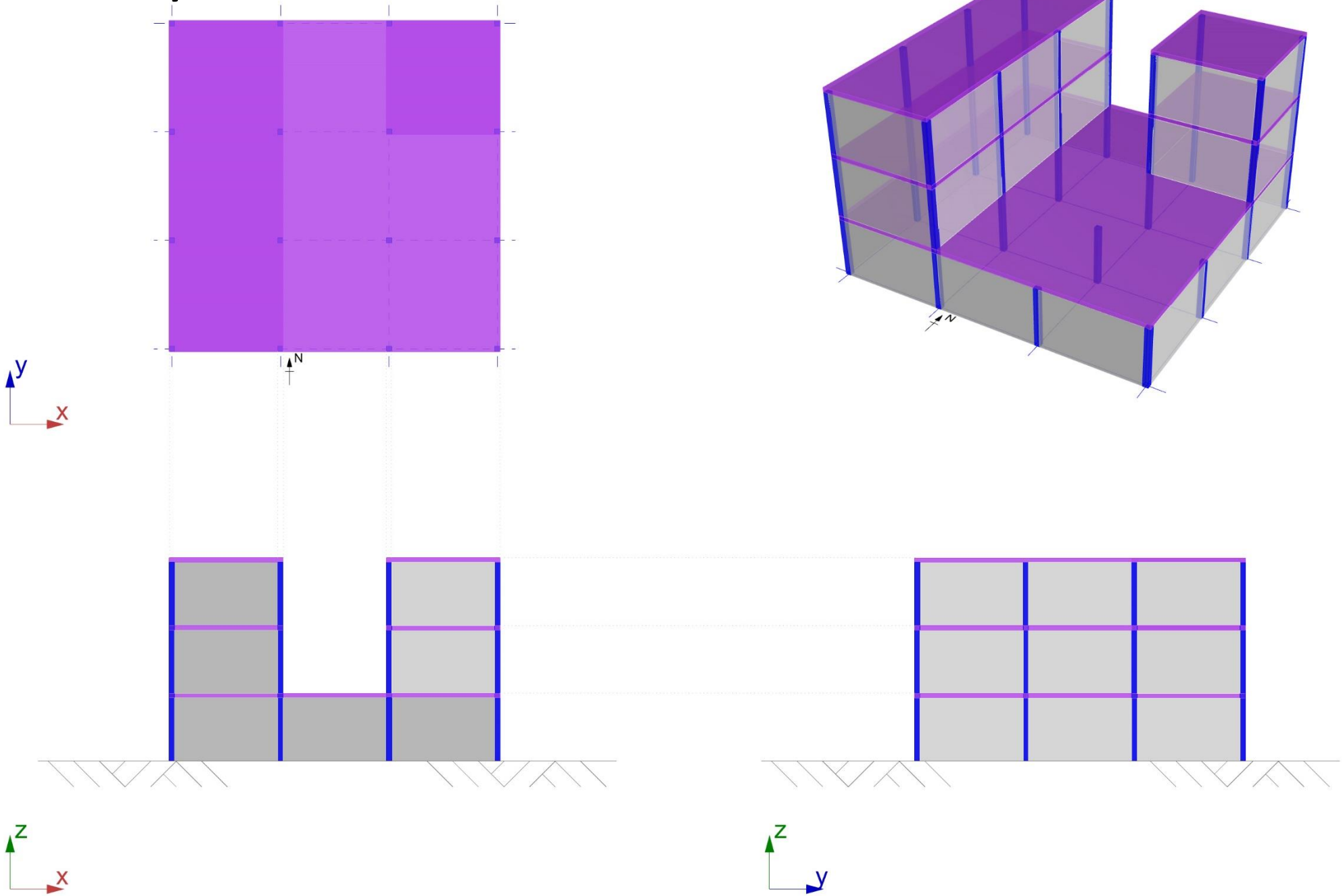
South Wind Load Path



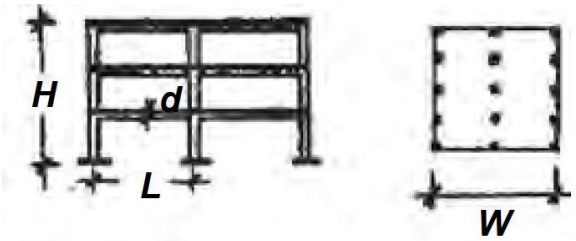
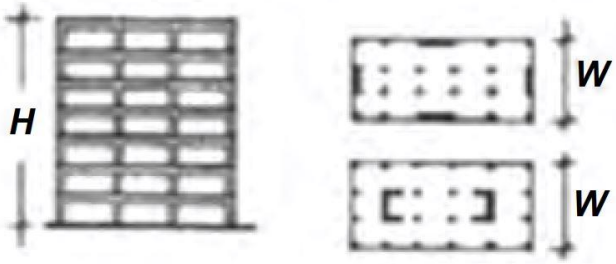
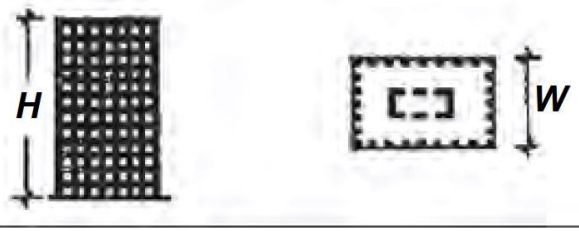
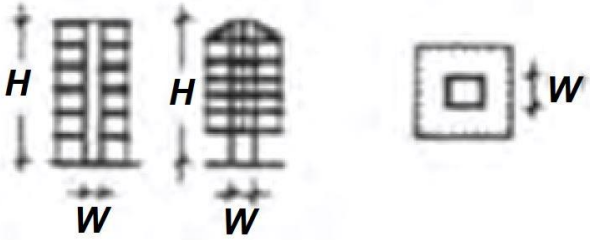
East Wind Load Path



Stability in Two Directions

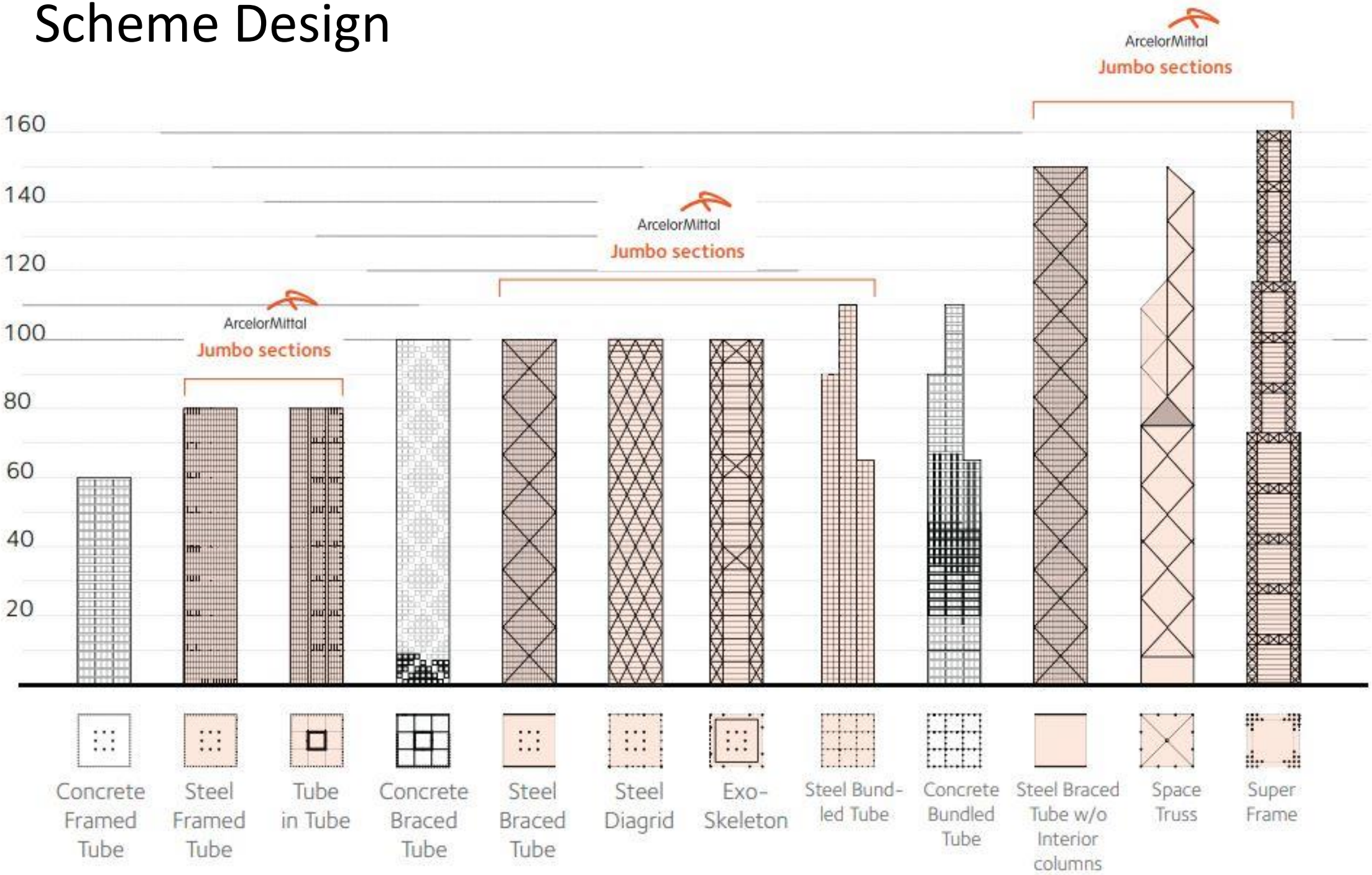


Scheme Design

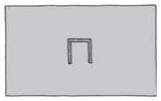
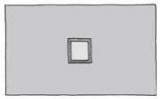
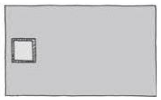
Element	Section and plan	Typical heights (H) (storeys)	Typical H/W	Remarks
Multi-storey cast-in-place frames		5–15 storeys	1–5	Cast-in-place frames without extra vertical bracing are economic up to about 15 storeys L/d ratio about 20–40
Shear walls or cores with rigid frame		10–55 storeys	4–5	Shear wall or core interacts with rigid frame to provide a vertical bracing system which is stiff over height of building Given values of height ratio (H/W) larger for buildings less than about 20 storeys high
Framed tubes and core		40–65 storeys	6–7	Also known as tube in tube system Framed tube interacts with core
Core structures with suspended floors or semi-rigid frame		10–30 storeys	8–12	Core provides all lateral stability Only limited plan areas with suspended floors

Stability - Littlefield, D. (2008) Metric Handbook Planning and Design Data - Chapter 36-31

Scheme Design



Scheme Design

Plan layout	Stability		Service	Redundancy		
	Resistance in two orthogonal axes	Torsional resistance	Slab free to move	Distributed systems	Resistance in two orthogonal axes	Residual torsional resistance
1 	✓	✱ Unstable	⊘ Restrained between systems	✓	✓	✱ Unstable
2 	✓ to ⊘ Depending on building plan shape, dimensions and scale	✓ to ⊘ Depending on building plan shape, dimensions and scale	✓ But slab movement may cause minor axis bending of the stability systems	✓	☒ No redundancy	☒ No redundancy
3 	✓	✓	✓ But slab movement may cause minor axis bending of the stability systems	✓	✓	✓ to ⊘ Depending on building plan shape, dimensions and scale
4 	✓	✓	⊘ Restrained between systems	☒ Failure at a corner would impact on two systems leaving only two intact	✓	☒ Failure at a corner would impact on two systems leaving only two intact
5 	✓ to ⊘ Depending on building plan shape, dimensions and scale	✓ to ⊘ Depending on building plan shape, dimensions and scale	✓	☒ Single concentrated system	☒ No redundancy. The core is a key element	☒ No redundancy. The core is a key element
6 	✓	✓ to ⊘ Depending on building plan shape, dimensions and scale	✓	☒ Single concentrated system	☒ No redundancy. The core is a key element	☒ No redundancy. The core is a key element
7 	✓	⊘ Large lever arm between the centres of stiffness and mass	✓	☒ Single concentrated system	☒ No redundancy. The core is a key element	☒ No redundancy. The core is a key element
8 	✓	✓	⊘ Restrained between systems	✓	✓	⊘ Large lever arm between the centres of stiffness and mass

Legend

✓ Denotes inherently good performance.

⊘ Denotes unwelcomed characteristics that may or may not be critical (depending on the plan geometry) and may be alleviated via careful detailing.

☒ Denotes instability in the event that a single stability structure fails. Design parameters for the stability elements must be justified based on an assessment of risk.

✱ Denotes inadequate performance.

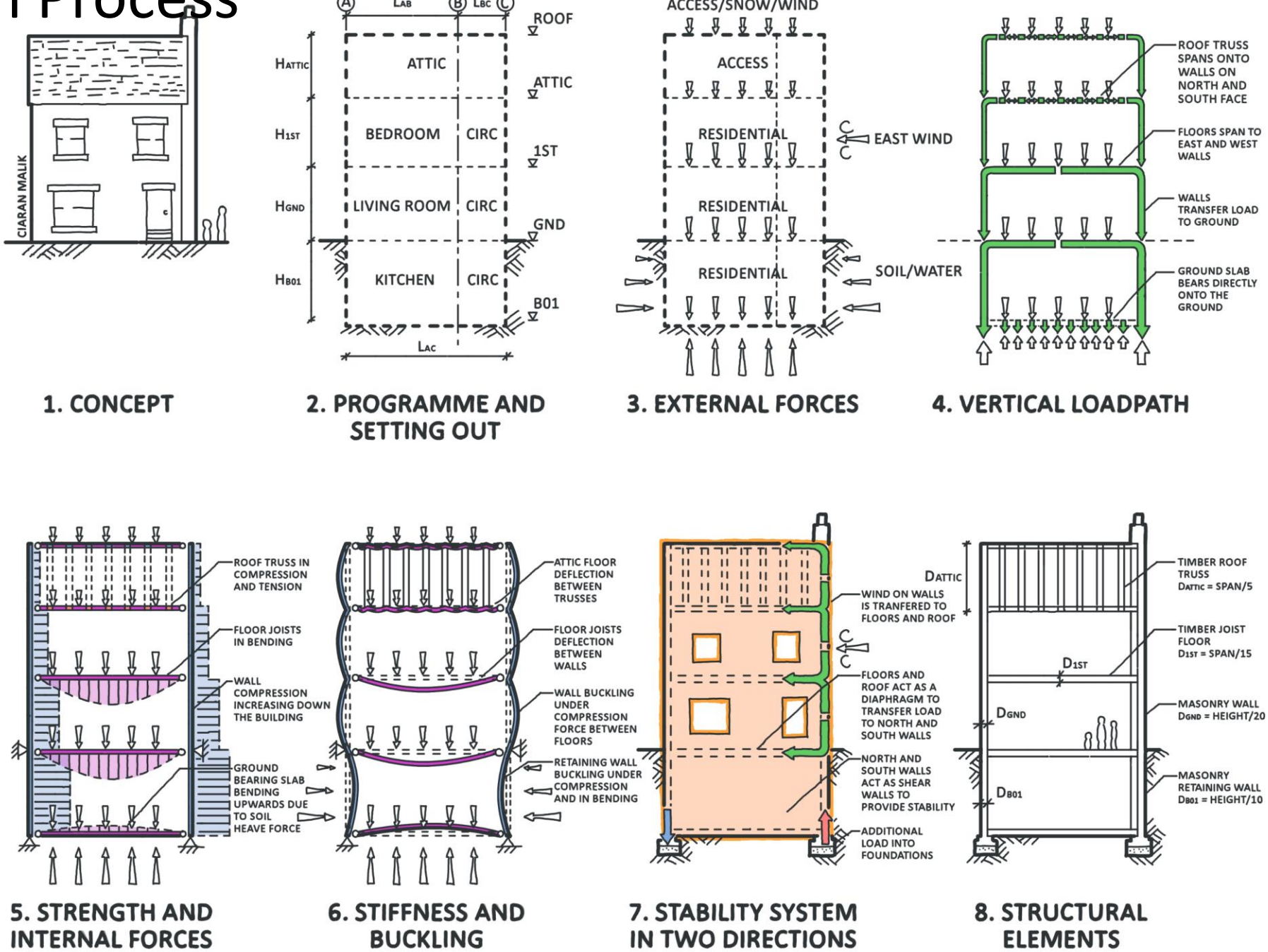
Note

Compatible combinations of the above layouts may be adopted to combine favourable characteristics.

Figure 4.4 Vertical stability layouts on plan

Stability - Stability of Buildings Part 1 and 2 General Philosophy and Framed Bracing (IStructE) page 17

Design Process



Key points

1. Horizontal loads

2. Stability systems; shear walls, bracing, outriggers, inherent stability, A-frame, moment frame, cantilever columns.

3. Horizontal load path; façade, diaphragm floor, stability elements

4. Stability in two directions

5. Scheme Design

Masterclass in Structural Behaviour
ETS3
3.1 Stability

Cíaran Malik

Third Year, First Term

2019-2020

Schedule

Time	Activity	By	
14:00-14:25	3.1 Stability	Cíaran	
14:30-14:55	3.2 Stability Exercise	Cíaran	
15:00-15:25	3.3 Lighting	Francisco	
15:45-16:00	Tutorials 4, 9, 14, 19	15:50-16:00	Scotts Pine
16:00-16:15	Tutorials 5, 10, 15, 20	16:00-16:10	Redwood
		16:10-16:20	Gum Tree
16:15-16:30	Tutorials 1, 6, 11, 16	16:20-16:30	Grandidier's Baobab
16:30-16:45	Tutorials 2, 7, 12, 17	16:30-16:40	Olive Tree
		16:40-16:50	Himalayan Birch
16:45-17:00	Tutorials 3, 8, 13, 18	16:50-17:00	Bamboo