Masterclass in Structural Behaviour

ETS3

3.1 Stability

Cíaran Malik

Third Year, First Term

2019-2020
<table>
<thead>
<tr>
<th>Time</th>
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<td>Grandidier's Baobab</td>
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<td>16:30-16:40</td>
<td>Olive Tree</td>
<td></td>
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<tr>
<td>16:40-16:50</td>
<td>Himalayan Birch</td>
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<td>16:50-17:00</td>
<td>Bamboo</td>
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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

1. CONCEPT

2. PROGRAMME AND SETTING OUT

3. EXTERNAL FORCES

4. VERTICAL LOADPATH

5. STRENGTH AND INTERNAL FORCES

6. STIFFNESS AND BUCKLING

7. STABILITY SYSTEM IN TWO DIRECTIONS

8. STRUCTURAL ELEMENTS
Building Loads

Dead - finishes self-weight.

Live - people/furniture
- rain
- snow
- wind
- soil
- flooding
- eq
Building Loads

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

Wind

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

**SHEAR WALLS**
Solid wall in bending

**BRACING**
Triangulated elements in tension and compression

**OUTRIGGERS**
External elements in tension or compression

**INHERENT STABILITY**
Shape is stable and able to resist horizontal forces

**A-FRAME**
Inclined elements tied together

**MOMENT FRAME**
Moment connections between columns and beams

**CANTILEVER COLUMNS**
Columns with a moment connection at the base
Stability Systems

Shear Walls

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

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

Form Surface-Active, Masonry Vault, Droneport Prototype 2016, Philippe Block
Form Frame Structure, Steel Frame with Timber, Maison Démontable in France 1944 (structure), Jean Prouvé

Stability Systems
Moment Frame
Stability Systems
Cantilever Column

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

1. Concept
2. Programme and Setting Out
3. External Forces
4. Vertical Load Path

5. Strength and Internal Forces
6. Stiffness and Buckling
7. Stability System in Two Directions
8. Structural Elements
Concept
Internal Forces
Load Path
Stability
Internal Forces

Elements:
- Beam
- Column
- Arch
- Slab
Elements
Elements

- Non-structural cladding
- Floor slab in bending
- Columns in compression
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

Some examples of bracing alternatives for multi-bays:

- X bracing
- K + X bracing
- Diaphragm
- X bracing + Diaphragm
- External bracing
- Diaphragm
- Stiff joint + X bracing + Diaphragm
- Shift joint
- Mixed bracing
Stability in Two Directions
Stability in Two Directions
South Wind Load Path, Perimeter System
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

<table>
<thead>
<tr>
<th>Element</th>
<th>Section and plan</th>
<th>Typical heights ($H$)</th>
<th>Typical $H/W$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-storey cast-in-place frames</td>
<td><img src="image1" alt="Diagram" /></td>
<td>5–15 storeys</td>
<td>1–5</td>
<td>Cast-in-place frames without extra vertical bracing are economic up to about 15 storeys $L/d$ ratio about 20–40</td>
</tr>
<tr>
<td>Shear walls or cores with rigid frame</td>
<td><img src="image2" alt="Diagram" /></td>
<td>10–55 storeys</td>
<td>4–5</td>
<td>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</td>
</tr>
<tr>
<td>Framed tubes and core</td>
<td><img src="image3" alt="Diagram" /></td>
<td>40–65 storeys</td>
<td>6–7</td>
<td>Also known as tube in tube system Framed tube interacts with core</td>
</tr>
<tr>
<td>Core structures with suspended floors or semi-rigid frame</td>
<td><img src="image4" alt="Diagram" /></td>
<td>10–30 storeys</td>
<td>8–12</td>
<td>Core provides all lateral stability Only limited plan areas with suspended floors</td>
</tr>
</tbody>
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Scheme Design

[Diagram showing various structural types and their corresponding designs, including concrete framed tube, steel framed tube, tube in tube, concrete braced tube, steel braced tube, steel diagrid, exo-skeleton, steel bundled tube, concrete bundled tube, steel braced tube w/o interior columns, space truss, super frame.]
<table>
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<th>Stability</th>
<th>Service</th>
<th>Redundancy</th>
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<tr>
<td></td>
<td>Resistance to two orthogonal axes</td>
<td>Torsoal resistance</td>
<td>Slab free to move</td>
</tr>
<tr>
<td>1</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>✓</td>
<td>✓</td>
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<tr>
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Legend:
- Denotes inherently good performance.
- Denotes unwelcome 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.
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