AGENDA

Session 1
Introduction to Building Maintenance Units (BMUs)

Session 2
Design principles of BMUs

Session 3
Safety features and regulatory design requirements of BMUs

Session 4
Temporary Gondola design for construction use
PROJECT EXAMPLE: CTF TIANJIN

- 530 metres
- Outward sloping façade
- Limited space at roof

- 1 BMU at top
- 4 BMUs at L71 with complete coverage
- Splits tower into two smaller towers
- Reduced travel times
- Reduced BMU quantity
○ Roof BMU (red) does not need to access below L71.
○ How to get glass from ground to top?
SESSION 3

Safety features and regulatory design requirements

TODAY’S AGENDA

1. Design standards
2. Wheel loads
3. Safety features
4. Design life
5. Inspection, examination and test
6. Testing details
7. Training
INTERNATIONAL STANDARDS

○ Project location determines standard
○ EN 1808 often required in China and HK specifications
○ Consultant may add additional standards

HONG KONG STANDARDS

Code of Practice for Safe Use and Operation of Suspended Working Platforms

For suppliers, building management, operators

Guidance Notes on the Inspection, Thorough Examination and Testing of Suspended Working Platforms

For RPE (registered professional engineers)
○ Based on and similar to EN1808
○ Less detailed than EN1808 (e.g. restraints)
○ Higher wind loads (20 m/s vs 31 m/s)
○ Higher stability requirements (3:1 vs 2:1)

TODAY’S AGENDA
1. Design standards
2. Wheel loads
3. Safety features
4. Design life
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7. Training
WHEEL LOADS

DEFINING THE LOADS

- 4 wheels
- Vertical and horizontal loads
- Loads vary depending on jib direction (0-90°)
TYPICAL WHEEL LOAD TABLE

- BMU supplier provides this table to the client for roof design
- Is it factored? Do the building engineers need to add extra factors?

![Wheel Load Table Diagram]

**Wheel Load Summary**

<table>
<thead>
<tr>
<th>Angle of track</th>
<th>Av (kg)</th>
<th>Bv (kg)</th>
<th>Cv (kg)</th>
<th>Dv (kg)</th>
<th>Ah (kg)</th>
<th>Bh (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90° Static</td>
<td>12,311</td>
<td>12,311</td>
<td>4,116</td>
<td>4,116</td>
<td>479</td>
<td>478</td>
</tr>
<tr>
<td>45° Static</td>
<td>14,006</td>
<td>9,214</td>
<td>2,419</td>
<td>9,214</td>
<td>693</td>
<td>272</td>
</tr>
<tr>
<td>0° Static</td>
<td>12,311</td>
<td>4,116</td>
<td>4,116</td>
<td>12,311</td>
<td>768</td>
<td>187</td>
</tr>
</tbody>
</table>

**Load Case 1 (In-service conditions)**

<table>
<thead>
<tr>
<th>Angle of track</th>
<th>Av (kg)</th>
<th>Bv (kg)</th>
<th>Cv (kg)</th>
<th>Dv (kg)</th>
<th>Ah (kg)</th>
<th>Bh (kg)</th>
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</thead>
<tbody>
<tr>
<td>90°</td>
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<td>15,368</td>
<td>5,146</td>
<td>5,146</td>
<td>597</td>
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<td>45°</td>
<td>17,510</td>
<td>10,267</td>
<td>3,024</td>
<td>10,267</td>
<td>654</td>
<td>340</td>
</tr>
<tr>
<td>0°</td>
<td>15,368</td>
<td>5,146</td>
<td>5,146</td>
<td>15,368</td>
<td>961</td>
<td>239</td>
</tr>
</tbody>
</table>

**Load Case 2b (Out of service)**

<table>
<thead>
<tr>
<th>Angle of track</th>
<th>Av (kg)</th>
<th>Bv (kg)</th>
<th>Cv (kg)</th>
<th>Dv (kg)</th>
<th>Ah (kg)</th>
<th>Bh (kg)</th>
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<tbody>
<tr>
<td>90°</td>
<td>5,116</td>
<td>5,116</td>
<td>9,926</td>
<td>9,926</td>
<td>1,421</td>
<td>1,421</td>
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<tr>
<td>45°</td>
<td>4,141</td>
<td>7,471</td>
<td>10,901</td>
<td>7,471</td>
<td>2,259</td>
<td>594</td>
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<tr>
<td>0°</td>
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<td>9,926</td>
<td>5,116</td>
<td>2,606</td>
<td>237</td>
</tr>
</tbody>
</table>

**Worst Case**

- SWL: 240kg for 2 persons plus tools (Safe working load)
- Cradle: 130kg for 2m long
- Wire ropes: 200kg for 200m x 4 ropes x 0.25 kg/m (Φ8mm)
- TSL: 570kg (Total suspended load)
Materials: 400kg inc GHU (1000kg maximum by EN1808)
Wire rope: 50kg for 200m x 0.25 kg/m (Φ8mm)
TSHL: 450kg (Total suspended hoist load)

Mo (Mass outboard): Jib + Crossbar
Mi (Mass inboard): Mast + baseframe + hoist + counterweight

Add enough counterweight so there is always static downloads

Wind loads: 31 m/s HK, 20 m/s EN1808
- Sum moments and forces to get wheel loads
- Static operating case is unfactored
- Out of service case is unfactored
- What are the factors on Load Case 1 and Stability?

**EN1808 LOAD CASE 1**
- To account for dynamic effects, basically add 25% to static

### Load Case Summary

<table>
<thead>
<tr>
<th>Load Case Static Operating</th>
<th>Av</th>
<th>Bv</th>
<th>Cv</th>
<th>Dv</th>
<th>Ah</th>
<th>Bh</th>
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</thead>
<tbody>
<tr>
<td>90</td>
<td>12.311</td>
<td>12.311</td>
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<td>4.116</td>
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<td>4.116</td>
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<td>768</td>
<td>187</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Case 1 (in-service conditions)</th>
<th>Av</th>
<th>Bv</th>
<th>Cv</th>
<th>Dv</th>
<th>Ah</th>
<th>Bh</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
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<td>15.368</td>
<td>5.146</td>
<td>5.146</td>
<td>587</td>
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<td>45</td>
<td>17.510</td>
<td>10.267</td>
<td>3.024</td>
<td>10.267</td>
<td>654</td>
<td>340</td>
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<tr>
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<td>15.368</td>
<td>5.146</td>
<td>5.146</td>
<td>15.368</td>
<td>961</td>
<td>239</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Case 2b (Out of service) (Jib retracted, no cradle)</th>
<th>Av</th>
<th>Bv</th>
<th>Cv</th>
<th>Dv</th>
<th>Ah</th>
<th>Bh</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5.116</td>
<td>9.926</td>
<td>9.926</td>
<td>1.421</td>
<td>1.421</td>
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<td>10.931</td>
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<td>9.826</td>
<td>5.116</td>
<td>2.606</td>
<td>239</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Working stability</th>
<th>Av</th>
<th>Bv</th>
<th>Cv</th>
<th>Dv</th>
<th>Ah</th>
<th>Bh</th>
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</thead>
<tbody>
<tr>
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<td>-</td>
<td>151</td>
<td>151</td>
<td>336</td>
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<td>-</td>
<td>151</td>
<td>-</td>
<td>19.259</td>
<td>-</td>
</tr>
</tbody>
</table>

**EN1808-2015**
- Total static BMU mass excluding SWL = 32,370 kg
- Stability code = EN1808-2015
EN1808 STABILITY

○ Theoretical loads. HK code uses factor of 3 instead of 2.

○ Adding a further factor of 4 for roof design not necessary

What additional factors should be applied to the building?

<table>
<thead>
<tr>
<th>Working stability</th>
<th>Total suspended load (N)</th>
<th>Weight of outboard portion (N)</th>
<th>Weight of inboard portion (N)</th>
<th>Horizontal force (Fh) (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2 \times TSL + 1.4 \times TSHL$</td>
<td>$1.25 \times Mo$</td>
<td>$1 \times Mi$</td>
<td>$1.25 \times Fw1 Plat + 1.25 \times Fw1 Rig$</td>
</tr>
</tbody>
</table>

Wheel Load Summary

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Angle (deg)</th>
<th>Av (kg)</th>
<th>Bv (kg)</th>
<th>Cv (kg)</th>
<th>Dv (kg)</th>
<th>Ah (kg)</th>
<th>Bh (kg)</th>
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</thead>
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<td>Operating</td>
<td>90</td>
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<td>12,311</td>
<td>4,116</td>
<td>4,116</td>
<td>478</td>
<td>478</td>
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<tr>
<td></td>
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<td>8,214</td>
<td>2,419</td>
<td>8,214</td>
<td>683</td>
<td>272</td>
</tr>
<tr>
<td></td>
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<td>12,311</td>
<td>4,116</td>
<td>4,116</td>
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<td>769</td>
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</tr>
<tr>
<td>1.25x</td>
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<td>15,388</td>
<td>5,146</td>
<td>5,146</td>
<td>597</td>
<td>597</td>
</tr>
<tr>
<td>In-service</td>
<td>45</td>
<td>17,519</td>
<td>10,267</td>
<td>3,024</td>
<td>10,267</td>
<td>664</td>
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<td>15,388</td>
<td>5,146</td>
<td>5,146</td>
<td>15,388</td>
<td>961</td>
<td>233</td>
</tr>
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<td>2.5x</td>
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<td>5,116</td>
<td>5,116</td>
<td>9,826</td>
<td>9,826</td>
<td>1,421</td>
<td>1,421</td>
</tr>
<tr>
<td>Out of</td>
<td>45</td>
<td>4,414</td>
<td>7,471</td>
<td>10,901</td>
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<td>2,269</td>
<td>584</td>
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<td>9,826</td>
<td>9,826</td>
<td>5,116</td>
<td>2,606</td>
<td>237</td>
</tr>
<tr>
<td>Working</td>
<td>90</td>
<td>18,259</td>
<td>18,259</td>
<td>151</td>
<td>151</td>
<td>336</td>
<td>336</td>
</tr>
<tr>
<td>stability</td>
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<td>22,072</td>
<td>9,064</td>
<td>3,963</td>
<td>9,064</td>
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<td>237</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>18,259</td>
<td>151</td>
<td>151</td>
<td>18,259</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total static BMU mass excluding SML = 32,370 kg
Stability code = EN1808-2015
**PARTIAL SAFETY FACTORS FOR EUROCODES**

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Factor yf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load case 1 (EN1808)</td>
<td>1.6</td>
</tr>
<tr>
<td>Out of service (EN1808)</td>
<td>1.4</td>
</tr>
<tr>
<td>Working stability (EN1808)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

\[ S_d = S_k \cdot y_f \]

**Sd = Design value of the load (Sd from Eurocodes)**

**Sk = Characteristic loads (inc. dynamic factors)**

**Yf = Partial safety factor on the loads**

For structural engineers using the **limit state method** as per Eurocodes **EC1 and EC3**, it is recommended that the following factors be applied by the as a minimum to the load cases for the purpose of identifying the design loads for the superstructure (building). However it is the responsibility of the structural engineer to ensure imposed loads for the SAE are accounted for in the superstructure design.

○ Request the extra information from the supplier
FINAL NOTE: UPLIFT

- BMUs generally counterweighted to ensure downloads
- Stability case may still show uplift
- Track and support design must consider the uplift

TODAY'S AGENDA

1. Design standards
2. Wheel loads
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SAFETY FEATURES

- 2 ropes each side
- 12:1 factor of safety (EN1808)
- Harness anchor for roof-mounted hoists
- Consider rescue plan after fall-arrest

PROTECTION FROM WIRE ROPE FAILURE
**PROTECTION FROM WIRE ROPE FAILURE**
- Platform mounted hoists need separate lifeline
- Permanent suspended platform: can anchor to roof rig
- Temporary suspended platform: must anchor to roof structure

**PROTECTION FROM UNBALANCED CRADLES**
- Platform mounted hoists
  - Level sensor to prevent more than 14° incline
  - Operators then can manually adjust each motor
  - EN1808 requirement
Roof mounted hoists
- Drums with a single layer of rope not affected
- Single layer not suitable for tall buildings
- Drums with multiple rope layers can have issues
PROTECTION FROM UNBALANCED CRADLES

- Layering sensor for roof mounted hoists
- Ensures even layering

- Prevent lowering or raising onto façade features
- Prevent imbalance, protect façade
PROTECTION FROM OVERLOAD

- Sensors in cradle
- Current monitoring in hoist motor

PROTECTION FROM OVERLOAD

- Restraint trip sensors
PROTECTION FROM OVERLOAD
- Lifting limit switch
- Ultimate lifting limit switch
- Same for materials hoist

PROTECTION FROM UNDERLOAD
- Avoid excess / slack rope build up in system
- Optical sensor
PROTECTION FROM HOIST FAILURE

- Example: drive motor failure
- Secondary brake required (primary = motor brake)
- 2 options for implementation

SECONDARY BRAKE: OPTION 1

- Overspeed governor example from an elevator
SECONDARY BRAKE: OPTION 1
- Overspeed governor

SECONDARY BRAKE: OPTION 1
- Testing video from BMU hoist
SECONDARY BRAKE: OPTION 2
- Fail-to-safe electrical monitoring of speed
- Fail-to-safe mechanically applied, hydraulic release brake
- Hydraulic power pack has manual mode for emergencies

MANUAL LOWERING OF HOIST
1. PRESS E-STOP
2. HAND PUMP LEVER
3. HYDRAULIC BRAKE MANUAL RELEASE BUTTON
4. MOTOR BRAKE RELEASE HANDLE

Lowering speed controlled by capacitor bank
**ELECTRICAL INTERLOCKS**
- Key lock operation
- Cradle at top limit for motions
  - Where possible
- Jib retracted during long travel
- Design benefits, cost reduction

**TODAY’S AGENDA**
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BREAK: 10 MINUTES

HOW LONG WILL IT LAST?

- BMUs are designed for the life of the building
- Regular maintenance in line with manufacturer requirements will ensure long life
- Mechanical and electrical parts will need to be replaced
- Structure is galvanised, painted, but requires monitoring
- Warranty generally 12 months
REPLACEMENT BMUs
- More common on old buildings
- Upgrade safety
- Reduce maintenance downtime
- Ensure loads ≤ old BMU
  - Site measurement
  - Load cells

REPLACEMENT BMU: EXAMPLE
- Wing On Centre Sheung Wan
- ~30 years old
- Increase safety and reduce maintenance
REPLACEMENT BMU: EXAMPLE

- Step 1: Erect temporary boom
- Boom parts carried in freight elevator
- Smaller boom can be needed to lift bigger boom

REPLACEMENT BMU: EXAMPLE

- Step 2: Remove old BMU
- Step 3: Install new BMU
  (& track)
TODAY’S AGENDA

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INSPECTION, EXAMINATION AND TEST

- Inspection on day of use
- Inspection within 7 days of use
- Examination within 6 months of use
- Testing within 12 months of use

Only required when BMU is in use

WHO IS RESPONSIBLE?

“The Owner”. This can include:

- The lessee or hirer
- Any overseer, foreman, agent or person in charge
- Contractor responsible for the construction site

- Code of practice has special legal status
- Failure to comply is not an offence, but could be considered in court
WHO CAN **INSPECT?**

A "Competent Person"

- Appointed by the owner to ensure that the duty is carried out
- By reason of substantial training and practical experience, competent to perform the duty

WHO CAN **EXAMINE AND TEST?**

A “Competent Examiner”

- Appointed by the owner to ensure thorough examination or load test is carried out
- A registered professional engineer within a relevant discipline (mechanical or marine engineer)
- By virtue of his previous experience, competent to carry out such thorough examination or load test
**INSPECTION: DAILY**
- By a competent person
- Inspect suspension ropes
- Inspect safety ropes
- No bolts loose or removed
- All connections sound

**INSPECTION: 7 DAYS**
- By a competent person
- Check for abnormal wear, corrosion, noise, misalignment
- Check hoist, ropes, platform, trolley
- Functional test of controls, limit switches, safety features

- Record and repair defects
- Retest and examine after repairs
- Statement issued in approved form (Form 1)
THOROUGH EXAMINATION: 6 MONTHS

- By a competent examiner
- Detect significant defects of critical parts
- All parts checked
- Full length of wire rope
- Functional test of controls, limit switches, safety features

- Record and repair defects
- Retest and examine after repairs
- Statement issued in approved form (Form 2)

TEST AND THOROUGH EXAMINATION: 12 MONTHS

- By a competent examiner
- Examination as per 6 month requirements
- Load test
- Load test also needed following:
  - Substantial repair
  - Re-erection (e.g. moving a davit)
  - Adjustments or modifications

- Record and repair defects
- Retest and examine after repairs
- Certificate issued in approved form (Form 3)
TODAY’S AGENDA

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TESTING DETAILS

Site tests
- Proof load test
- Overload device function test
- Operational test

Factory tests
- Similar to above, following EN1808
**PROOF LOAD TEST**

- By a competent examiner
- Static type test
- Check of structure, not functions
- 150% of cradle SWL
  - (e.g. 375kg for 250kg SWL)
- 125% of materials hoist SWL
  - Non-man carrying device
  - Materials hoist covered by “lifting appliances regulation”

**OVERLOAD DEVICE FUNCTION TEST**

- Check the cradle cannot become overloaded during operation
- By a competent examiner
- To manufacturer’s recommendations
OPERATIONAL TEST

- By a competent examiner
- 100% SWL
- 100% materials SWL
- Check all functions of BMU

ADDITIONAL TESTING

Client may request:

- Demonstrate all areas of facade accessible
- Maximum reach
- Complex drops, recesses
  - Pull-in restraints, telescopic cradle, etc
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TRAINING

- Not just window washers
- CoP requires every person to be trained and certified
- Construction Industry Council (CIC) holds training courses with certification
- Not project specific
- We recommend refresher training every 2 years
- At owner request, suppliers hold own training course for each building
FURTHER READING

- EN 1808 is easy to follow and contains example calculations

Q & A

Any questions?

Next session: tomorrow, 7pm with Peter Chan

peter.ransom@gmail.com