Tall Buildings: Prevention at the Design Stage – The view of an Occupational Safety and Health Expert

Carl Heyrman
Nicosia, Cyprus
January 14, 2017
Where I come from
Antwerp
Tall buildings of Antwerp

Cathedral

- Year: 1352-1521
- Height: 123 m
Tall buildings of Antwerp

‘Tower building’
- Year 1929-1932
- Height: 87.5m
- Heighest skyscraper of Europe in 1932
## Tall buildings of Antwerp

<table>
<thead>
<tr>
<th>Name</th>
<th>City</th>
<th>Country</th>
<th>Status</th>
<th>Built</th>
<th>Type</th>
<th>Height</th>
<th>Floors</th>
<th>Use</th>
<th>Antenna</th>
<th>Spire</th>
<th>Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fina Antwerp Olefins Flare 4</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1974</td>
<td>Industrial</td>
<td>185 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>185 m</td>
</tr>
<tr>
<td>Metallurgie Hoboken Chimney</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1974</td>
<td>Factory</td>
<td>152 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>152 m</td>
</tr>
<tr>
<td>Cathedral of Our Lady</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Religious</td>
<td>123 m</td>
<td>Office</td>
<td>123 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KBC Tower</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1932</td>
<td>Office</td>
<td>95.8 m</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antwerp Tower</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1974</td>
<td>Office</td>
<td>87 m</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicago Building</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>2014</td>
<td>Residential</td>
<td>81 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Park Tower</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>2010</td>
<td>Residential</td>
<td>78.8 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>London Tower</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1969</td>
<td>Mixed use</td>
<td>76.6 m</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Theater Building</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1967</td>
<td>Office</td>
<td>76 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Politietoren</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>Built</td>
<td>1967</td>
<td>Office</td>
<td>76 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

http://skyscraperpage.com/diagrams/?
Tall buildings ... New buildings?

- Great Pyramid (Giza)
- Eiffel Tower (Paris)
- Empire State (New York)
- Petronas Towers (Kuala Lumpur)
- Taipei 101 (Taipei)
- CN Tower (Toronto)
- Warsaw Radio Mast (Gabin)
- KVLY-TV Mast (Blanchard)
- Burj Khalifa (Dubai)
Empire State Building NY

- Ready in 1931
- 20 months from start to finish
- 3400 workers simultaneously
- At least 5 fatal accidents
Design and prevention
Construction life cycle

- Design stage
- Procurement stage
- Construction stage
- Use and maintenance stage
- Demolition stage
Direct parties concerned

- Client - Owner
- Designer
- Contractor
- Construction worker
- Site manager
- Supplier
- Safety expert
- ...

eurconsult
Role and impact of the designer

- Over 60% (*) of fatal accidents could have been avoided by taking action before opening the construction site

- Article 9 of the 167th ILO Convention: The designer must consider safety and health protection for construction workers

- EU 92/57

- The decisions taken during the initial cycles are the most strategic

(*) Source: ISSA-C
Role of the designer

Designers must study how the structure can be built, used, maintained, renovated and finally demolished safely.
Management of Health and Safety: Fields of action
Example: pre-fabrication

- Pre-fabrication and pre-assembly will likely increase worker safety
- Pre-fabrication reduces work at height
Recommendation 1

Be aware of the difference you can make as a designer regarding SH
Our old friends
Sir Isaac Newton (1643–1727)
Newton's first law: law of inertia

The first law can be stated mathematically when the mass is a non-zero constant, as,

\[ \text{SUM}(F) = 0 \iff \frac{dv}{dt} = 0 \]

Consequently

- An object that is at rest will stay at rest unless a force acts upon it
- An object that is in motion will not change its velocity unless a force acts upon it
Newton’s second law

- $F = m \frac{dv}{dt} = m \cdot a$

Derived
- $G = m \cdot g$

Newton

$(kg \cdot m/s^2)$

Where
- $g = 9.81 m/s^2 = \text{acceleration of free fall}$
- $m = \text{mass of the body}$
- $G = \text{Weight of the body}$
Newton’s third law

- To every action there is always opposed an equal reaction

or

- The mutual actions of two bodies upon each other are always equal, and directed to contrary parts
Potential Energy

\[ E_p = m \cdot g \cdot h \]

**Joule**

\((kg \cdot m/s^2 \cdot m = N \cdot m)\)
Kinetic Energy

$$E_k = \frac{1}{2} m v^2$$

Joule

($$\text{kg.m/s}^2 \cdot \text{m} = \text{N.m}$$)
Law of conservation of mechanical Energy

\[ E = E_p + E_k \]

Joule

\( (\text{kg.m/s}^2.\text{m}= \text{N.m}) \)
Impact on human head

University Bern (CH)

- 100J: Fracture of human scull
- 200J: Fatal
Impact of a concrete block
Impact of fall of a hammer of 450g
Impact of fall of a bold of 30g
STRUCTURAL BOLT

Height: 4.00 IN
Diameter: 1.00 IN
Weight: 1.00 LBS

Dropped from 30ft

2881.0 LBF
Recommendation 2

Stop dropped objects
Preventing dropped objects
Safety nets


Safety Net Fan High Rise

The Safety Net Fan High Rise has been designed specifically for the High Rise construction industry and can withstand winds of up to 100mph. It utilises the Class B1 net and comes with 60 x 60mm mesh and 20mm x 20mm debris net as standard, which has been proven to arrest falls of up to 100kg from a height of 6m, conforming to EN1263-152 (Safety Nets).

The elasticity of the net, together with a slight deformation of the frame, ensures that the impact of a fall is absorbed, considerably decreasing the risk of injury or objects falling to street level. Items do not bounce out or shatter which can harm people and property below. B1 nets that comply with EN1263-152 are significantly stronger than conventional methods of protection, as well as being energy absorbent, absorbing up to 4.4 kJ.

The combined layer net is able to catch considerably smaller particles of debris therefore protecting property and people at ground level. Fans can be folded in to retrieve fallen objects.

- Designed to withstand wind gusts of up to 100mph
- Made for catching material
- Compliments high rise construction
- 60mm x 60mm net overlay with 20 mm x 20mm* debris netting
- 6m long by 4.5m wide
- High energy absorbing nets and frame assembly
- Folds up against the facade for easy crane access below or as a safety precaution during bad weather

*on the main inner section only, not on the kicker "up section"

NOTE: This product is a special solution, made to order only.
The **force** of nature
Wind and structural design

- Structural integrity under ultimate loads
- Deflections under service loads
- Building motion and occupant comfort
- Uncertainties in building structural properties like stiffness and damping
- Uncertainties in wind loading
- Uncertainties in wind climate
- Fluid dynamics
Relationship between height and the importance of wind loads
Wind flow between buildings
Wind flow over tall buildings

Turbulence

$h$

$7-30 \times h$
Pressure

Diagram showing pressure patterns with areas marked as 'Standing whirl', 'Wake area', 'Pressure + high', and 'Pressure - low'. The diagram indicates flow patterns with a barrier in the middle, creating high and low pressure regions.
Aerodynamic buildings
Scale wind tunnel tests

Source: Peter A. Irwin RWDI
What about scaffolds?

From: Worksafe Victoria (Australia)
Recommendation 3

Assess the impact of wind also on scaffolds, platforms and temporary structures.
Make sure that...

- All scaffolds in wind exposed locations are designed to withstand likely environmental loads, including wind and rain.
- The design of a sheeted scaffold in any wind-exposed location is approved by a competent person.
- Where buildings or structures are being demolished, any adjacent scaffold is also progressively dismantled or, when it is still required, that it has been appropriately strengthened to withstand any increased wind loads.
- Planks on high scaffolds in wind-exposed locations are properly fixed against uplift.
When different people are working together
Culture and communication
Cultural diversity
Same gestures... different meanings
Languages and communication

Worldwide

- 7,000 official languages
- 20,000 dialects
Dáág !

Au revoir !

左様なら

Pacim !

Selamat jalan !

안녕

До свидания!
Miscommunication leads to mistakes

Miscommunicatie zorgt voor bouwfouten

Door Margreeth Fernhout
16 mei 2013 09:09 AM

De meeste constructiefouten worden gemaakt door slechte samenwerking en miscommunicatie. Dat blijkt uit grootschalig onderzoek onder bouwvakkers, door de TU Delft.
Miscommunication can also lead to accidents

Fatal accidents in Construction in the US (CPWR)

<table>
<thead>
<tr>
<th>Migrant workers (Hispanic)</th>
<th>Proportion of fatal accidents</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5%</td>
<td>11.2%</td>
<td>1992</td>
</tr>
<tr>
<td>15%</td>
<td>23.5%</td>
<td>2000</td>
</tr>
</tbody>
</table>
Possible explanations

- ... 
- Less knowledge of English 
- ...
Story of the Belgian Construction Industry in 2014

- 151,061 blue collar workers on a Belgian pay roll
- 87,792 foreign workers
Accidents in the Belgian construction industry (Frequency Index)

<table>
<thead>
<tr>
<th>Year</th>
<th>NACE 41</th>
<th>NACE 42</th>
<th>NACE 43</th>
<th>Totaal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>56,44</td>
<td>47,79</td>
<td>46,50</td>
<td>49,25</td>
</tr>
<tr>
<td>2012</td>
<td>39,22</td>
<td>43,82</td>
<td>44,61</td>
<td>47,28</td>
</tr>
<tr>
<td>2013</td>
<td>33,97</td>
<td>40,08</td>
<td>40,99</td>
<td></td>
</tr>
</tbody>
</table>

Source: eurconsult
What about the accident figures for foreign workers?
Observations made by Navb-Cnac

- Communication problems
  - Some workers do not speak the national languages, nor English
  - Therefore, safety instructions are not understood, Belgian regulations are not known
  - Communication with Belgian workers and site managers is complicated
- The taller the construction site, the more diverse it is
Recommendation 4

Be aware of diversity
Managerial aspects
Management of Health and Safety: Fields of action
Safety and health in construction

6.5. Mobile asphalt layers and finishers ............................................. 32
6.6. Pavers .................................................................................. 33
6.7. Road rollers ......................................................................... 33

7. Plant, machinery, equipment and hand tools ..................................... 34
  7.1. General provisions ................................................................ 34
  7.2. Hand tools ........................................................................... 35
  7.3. Pneumatic tools .................................................................... 35
  7.4. Cartridge-operated tools ..................................................... 36
  7.5. Electrical tools ..................................................................... 37
  7.6. Woodworking machines ..................................................... 37
  7.7. Engines ............................................................................... 38
  7.8. Silos ................................................................................... 38
  7.9. Concrete work equipment ................................................... 39
  7.10. Pressure plant .................................................................... 40
  7.11. Conveyors ......................................................................... 42
  7.12. Crusher plants ................................................................... 43
  7.13. Power generators .............................................................. 43

8. Work at heights including roof work .................................................. 44
  8.1. General provisions ................................................................ 44
  8.2. Roof work .......................................................................... 44
  8.3. Work on tall chimneys ......................................................... 45

9. Excavations, shafts, earthworks, underground works and tunnels ......... 47
  9.1. General provisions ............................................................... 47
  9.2. Excavations ......................................................................... 47
  9.3. Underground construction ................................................... 49
  9.3.1. General provisions ......................................................... 49
  9.3.2. Shaft sinking .................................................................... 49
  9.3.3. Ventilation ....................................................................... 51
  9.3.4. Fire protection ............................................................... 51
  9.3.5. Electricity ................................................................. 52
  9.3.6. Underground lighting ..................................................... 52
  9.4. Drilling ............................................................................... 52
  9.5. Transport, storage and handling of explosives ....................... 53
  9.6. Blasting ............................................................................. 53
  9.7. Haulage ............................................................................. 53
  9.8. Dust control ......................................................................... 54
  9.9. Underground pipelines ....................................................... 54

10. Cofferdams and caissons and work in compressed air ................. 55
    10.1. General provisions ............................................................ 55
    10.2. Work in cofferdams and caissons ...................................... 56
    10.3. Work in tunnels in compressed air ..................................... 59

11. Structural frames, formwork and concrete work ............................... 61
    11.1. General provisions ............................................................ 61
    11.2. Erection and dismantling of steel and prefabricated structures .... 61
    11.3. Cast-in-situ concrete structures ......................................... 64
    11.4. Provision of temporary floors ......................................... 64
    11.5. Formwork ....................................................................... 65
Recommendation 5

Implement a strict management system for Health and Safety through all stages of the construction project.
감사합니다

Danke Еуχαριστίες Dalu Köszönöm Tack

Спасибо Dank Gracias Seé

谢谢 Merci ありがとう