
1

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## Facade engineering and evolution towards advanced building envelopes

Topics :

- 25 years of evolution in facade design and engineering
- Current projects
- BIM approach during a building project
- Different knowledge areas needed within facade engineering
- Future evolutions
- Advanced building skins
- Facade engineering in Macedonia

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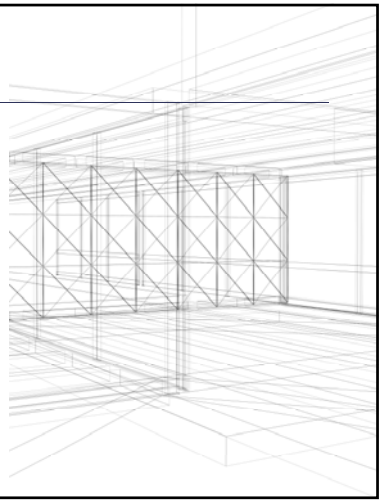
## 25 years of evolution in facade design and engineering

- University of Brussels : architect or engineer ?
- Tractebel Energy Engineering + Permasteel ISA
- Hydro Building Systems / Wicona / SAPA
- Reynaers Aluminium
- Belgian Federation of Aluminium Fabricators
- Independent consultancy



3

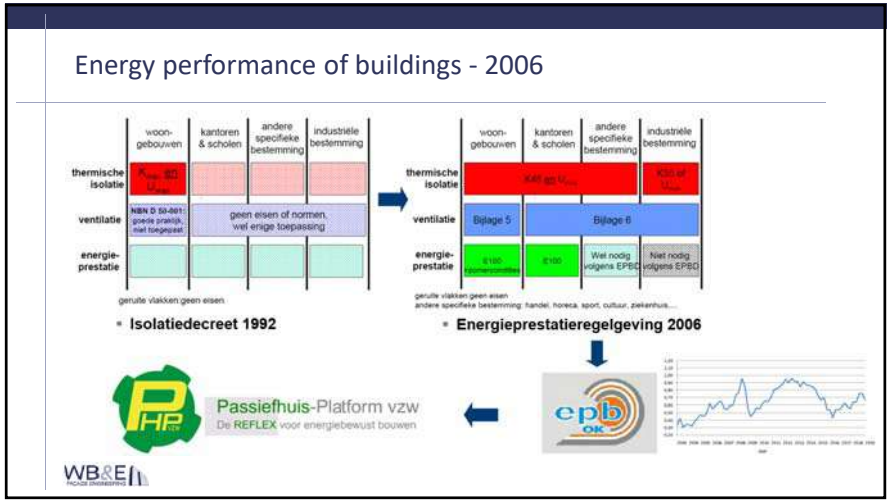

4


1998
Saint
COOL LITE

5

6

7


Energy performance of buildings - 2006
woon-gebouwen
kantoren & scholen
andere specifieke bestemming
industriële bestemming
thermische isolatie
ventilatie
energie-prestatie
geen eisen of normen, wel enige toepassing
Isolatiedecreet 1992
Bijlage 5
Bijlage 6
Wet nodig volgens EPBD
Niet nodig volgens EPBD
Energieprestatieregelgeving 2006
Passiefhuis-Platform vzw
De REFLEX voor energiebewust bouwen
epb
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## Race for insulation technology

| ENERGIE | | MASTERLINE 8 | | MASTERLINE 8 HI | | MASTERLINE 8 HI+ | | PASSIVE HOUSE | |
|---|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| Thermische Isolatie raam[1] EN ISO 10077-2 | Vast | 1,6 | 1,9 | 1,3 | 1,4 | 1,0 | 1,3 | | |
| | Kader/ vleugel | 1,7 | 2,1 | 1,4 | 1,6 | 1,1 | 1,4 | | |
| Thermische Isolatie deur[1] EN ISO 10077-2 | | | | 2 | | 1,4 | | 1,4 | |
| $U_f$ berekend met glasdikte | | 24 mm | | 36 mm | | 36 mm | | paneeldeur 76 mm | |

| reeks | max. Uf ( W/m² K) | min. Uf ( W/m² K) | rekenwaarde Uf ( W/m² K) |
|---|---|---|---|
| CS86-HI | 1,85 | 1,53 | **1,69** |
| CS77-HI | 1,98 | 1,91 | **1,93** |
| CS77 | 2,45 | 1,96 | **2,03** |
| Eco System | 2,55 | 2,25 | **2,33** |
| CS68 | 2,98 | 2,46 | **2,58** |
| CS38-SL nieuw | 2,70 | 2,94 | **2,71** |
| TS57 | 3,07 | 2,75 | **2,75** |
| CS59 | 3,73 | 3,08 | **3,23** |
| CS38-SL oud | 3,28 | 4,01 | **3,51** |
| TS50 | 4,39 | 4,00 | **4,22** |
| | profielcombinatie = kleinste vleugel kleinste kader | profielcombinatie = grootste vleugel grootste kader | profielcombinatie = kader 77 mm vleugel 59 mm |
| | Te beschouwen aanzichtsbreedte = 141 mm | | |


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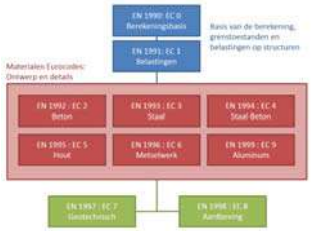
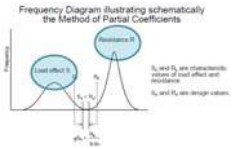



2007 → 2009




| Soort | Nummer | Jaartal | Omschrijving |
|---|---|---|---|
| NBN EN | 1990 | 2002 (incl NB) | Eurocode - Grondslagen van het constructief ontwerp (+AC:2010) |
| NBN EN | 1991-1-1 | 2002 (incl NB) | Eurocode 1 - Belastingen op constructies - Deel 1-1: Algemene belastingen - Volumieke gewichten, eigen gewicht en opgelegde belastingen voor gebouwen (+ AC:2009) |
| NBN EN | 1991-1-2 | 2003 (incl NB) | Eurocode 1: Belastingen op constructies - Deel 1-2: Algemene belastingen - Belasting bij brand (+ AC:2013) |
| NBN EN | 1991-1-3 | 2003 (incl NB) | Eurocode 1: Belastingen op constructies - Deel 1-3: Algemene belastingen - Sneeuwbelasting (+ AC:2009) |
| NBN EN | 1991-1-4 | 2005 (incl NB) | Eurocode 1: Belastingen op constructies - Deel 1-4: Algemene belastingen - Windbelasting (+ AC:2010) |
| NBN EN | 1999-1-1 | 2007 (incl NB) | Eurocode 9 - Ontwerp en berekening van aluminiumconstructies - Deel 1-1: Algemene regels (+A1:2009) |
| NBN EN | 1999-1-2 | 2007 (incl NB) | Eurocode 9 - Ontwerp en berekening van aluminiumconstructies - Deel 1-2: Ontwerp en berekening van constructies bij brand (+ AC:2009) |
| NBN EN | 1999-1-3 | 2007 (incl NB) | Eurocode 9- Ontwerp en berekening van aluminiumconstructies - Deel 1-3: Vermoeiing (+A1:2011) |
| NBN EN | 1999-1-4 | 2007 (incl NB) | Eurocode 9 - Ontwerp en berekening van aluminiumconstructies - Deel 1-4: Koudgevormde platen (+ AC:2009) |
| NBN EN | 1999-1-5 | 2007 (incl NB) | Eurocode 9 - Ontwerp en berekening van aluminiumconstructies - Deel 1-5: Schaalconstructies (+ AC:2009) |

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RAPPORT TOEPASSING VAN DE EUROCODES OP HET ONTWERP VAN BUITENSCHRIJNWERK

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## Construction Product Directive (CPD) - 2011

- Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products
  OJ No L 40 of 11 February 1989
- Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC
  OJ L 88 of 4 April 2011

ITT

\+

FPC

CE

01234

AnyCo Ltd. PO Box 21, B-1050

04

01234-CPD-00234

EN 14351-1:2004

Type XYZ- Roof window intended to be used in domestic and commercial locations

Resistance to wind load – Test pressure: Class C
Resistance to wind load – Frame deflection: Class B
Resistance to snow load: 4-10-4
Reaction to fire: Euroclass D
External fire performance: npd
Watertightness – Non-shielded (A): Class 9A
Watertightness – Shielded (B): npd
Impact resistance: 450
Load-bearing capacity of safety device Threshold value
Acoustic performance: 33 (-1; -5)
Thermal transmittance: 1,7
Radiation properties – Solar factor: 0,55
Radiation properties – Light transmittance: 0,75
Air permeability: Class 4

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## Initial type testing facade elements

- **Air, wind and water tests** (AWW)
- **Mechanical performances on profile systems**
  - Repeated opening and closing, durability
  - Mechanical strength, Racking & Torsion
  - Operating forces
- **Mechanical performances on insulated profiles**
  - Infra red lights
  - Climat chamber
  - Aging tests, QUV
  - Oven
- **Impact Resistance tests**
- **Burglar Proof Resistance tests**
- **Acoustic test**
- **Energy performance tests in R-cube**

R&D

CE - marking

Project testing

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Air permeability:
test method: EN 1026:2000 / EN 12153:2000
classification: EN 12207:1999 / EN 12152:2002
Water tightness under static pressure:
test method: EN 1027:2000 / EN 12155:2000
classification: EN 12208:1999 / EN 12154:1999
Resistance against wind load:
test method: EN 12211:2000 / EN 12211:2000
classification: EN 12210:1999 / EN 16116:2001
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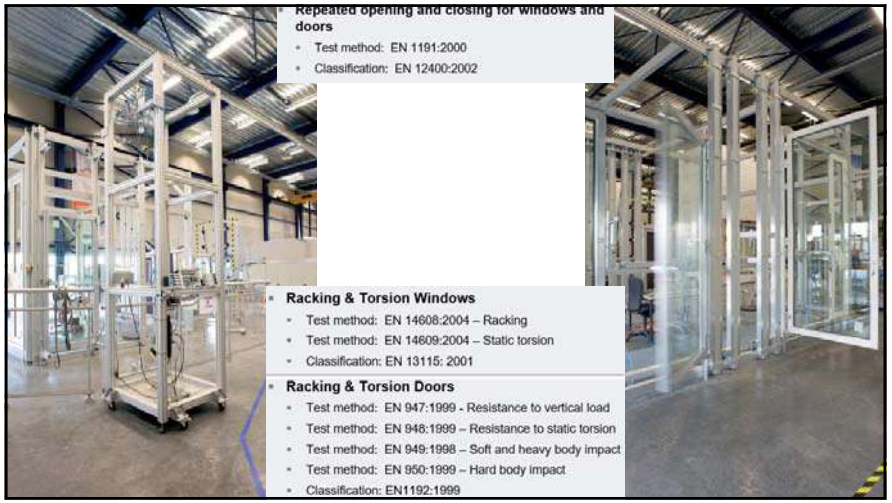
Repeated opening and closing for windows and doors
Test method: EN 1191:2000
Classification: EN 12400:2002
Racking & Torsion Windows
Test method: EN 14608:2004 – Racking
Test method: EN 14609:2004 – Static torsion
Classification: EN 13115: 2001
Racking & Torsion Doors
Test method: EN 947:1999 - Resistance to vertical load
Test method: EN 948:1999 – Resistance to static torsion
Test method: EN 949:1998 – Soft and heavy body impact
Test method: EN 950:1999 – Hard body impact
Classification: EN1192:1999

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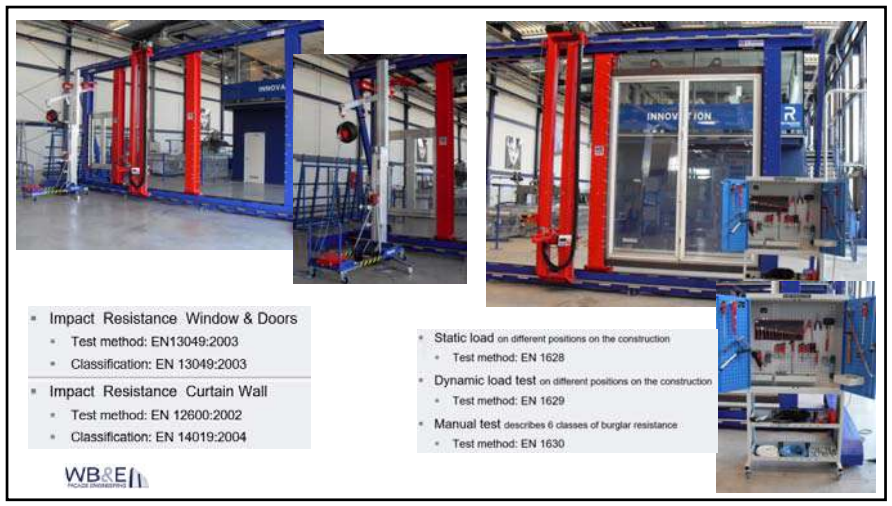
Impact Resistance Window & Doors
Test method: EN13049:2003
Classification: EN 13049:2003
Impact Resistance Curtain Wall
Test method: EN 12600:2002
Classification: EN 14019:2004
Static load on different positions on the construction
Test method: EN 1628
Dynamic load test on different positions on the construction
Test method: EN 1629
Manual test describes 6 classes of burglar resistance
Test method: EN 1630
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Measurement of sound insulation in buildings and building elements
Test method: EN ISO 10140-3
Rating of sound insulation in buildings and of building elements – Part1: Airborne sound insulation
Test method: EN ISO 717-1
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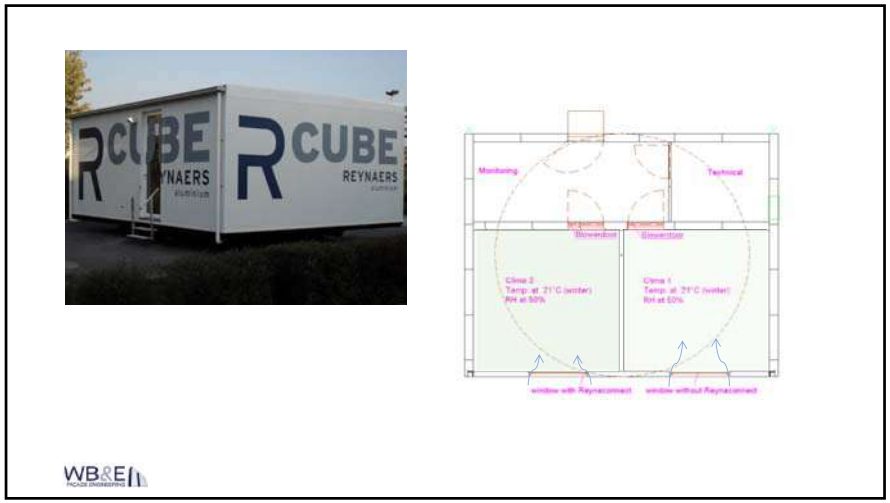


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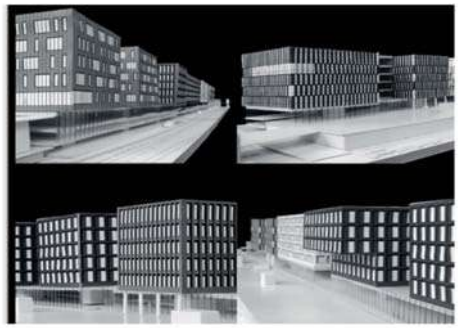
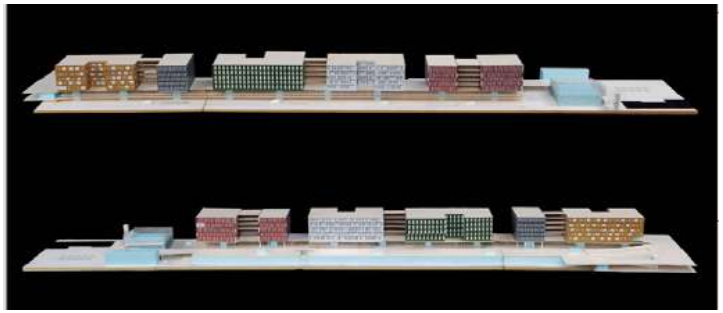
The architect, Crepain-Binst Architecture, created a range of five office buildings on a glass access plinth, along the railway.



23



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25

- The glass panels at the ground floor measure 2,7 m by 5,2 m. This means that the glass composition has to be 12/15/88.2
- Glass weight: approximately 1000 kg.

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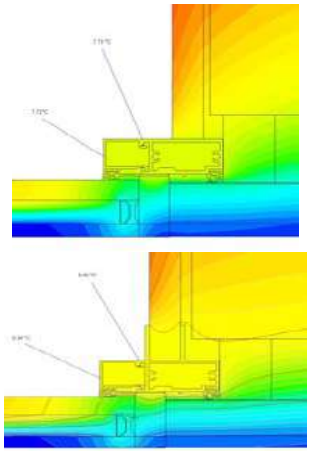

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More glass , no aluminium ! → Hi-Finity sliding doors


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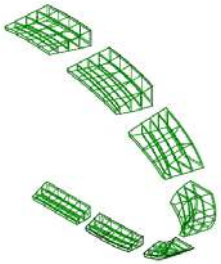

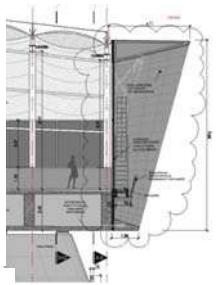

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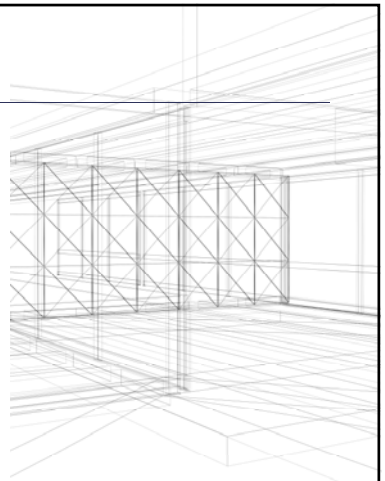
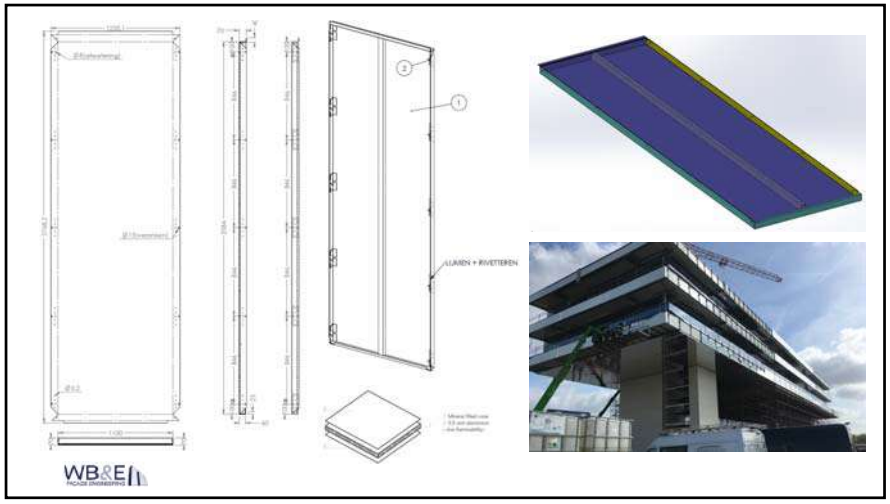
Current projects



32

33

34



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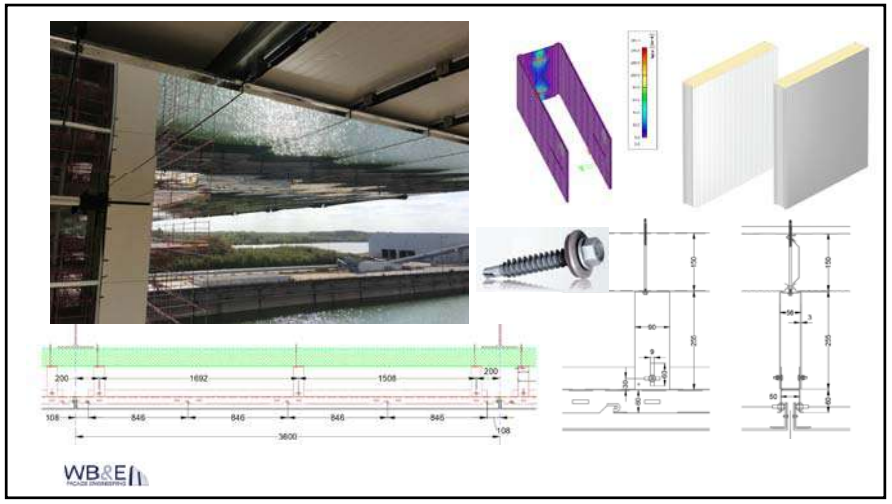

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Deloitte.
WB&E

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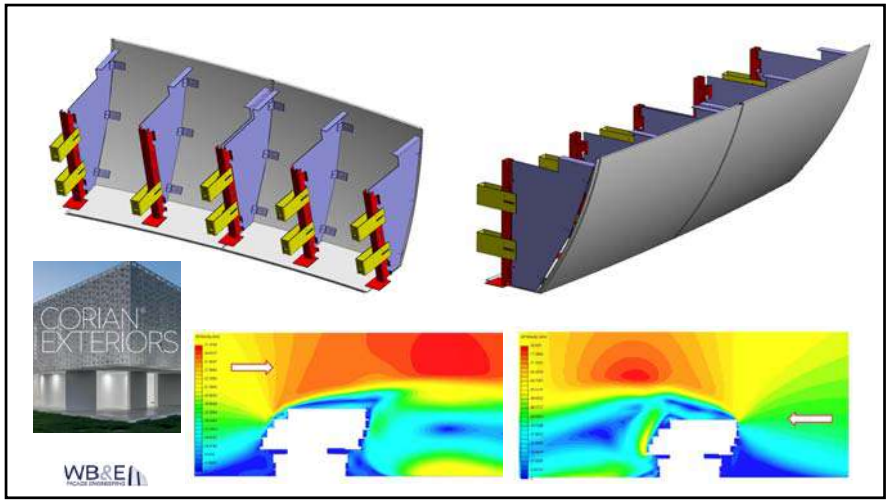
CORIAN
EXTERIORS
WB&E

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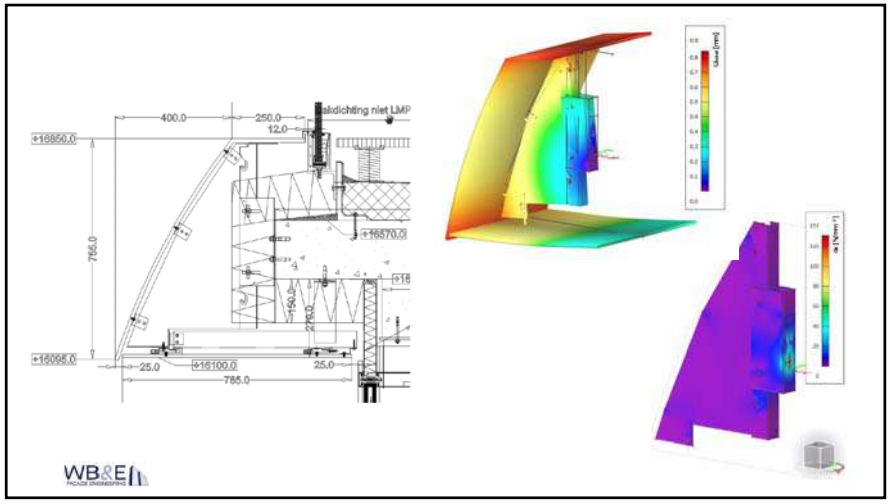
400.0
250.0
12.0
+18850.0
+16570.0
755.0
+16095.0
25.0
+16100.0
25.0
755.0
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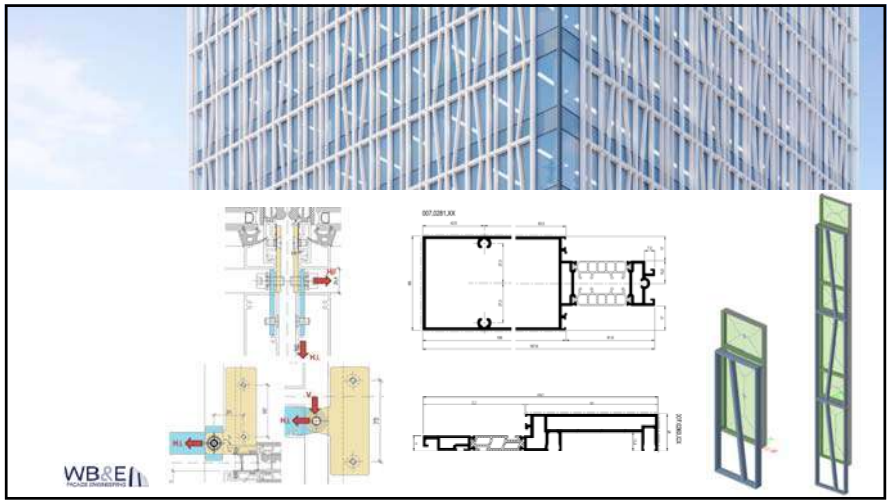
40

41



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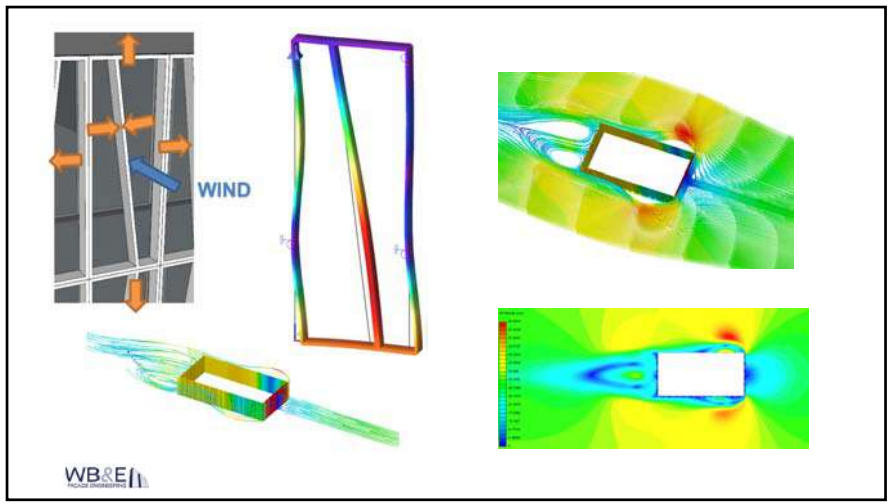


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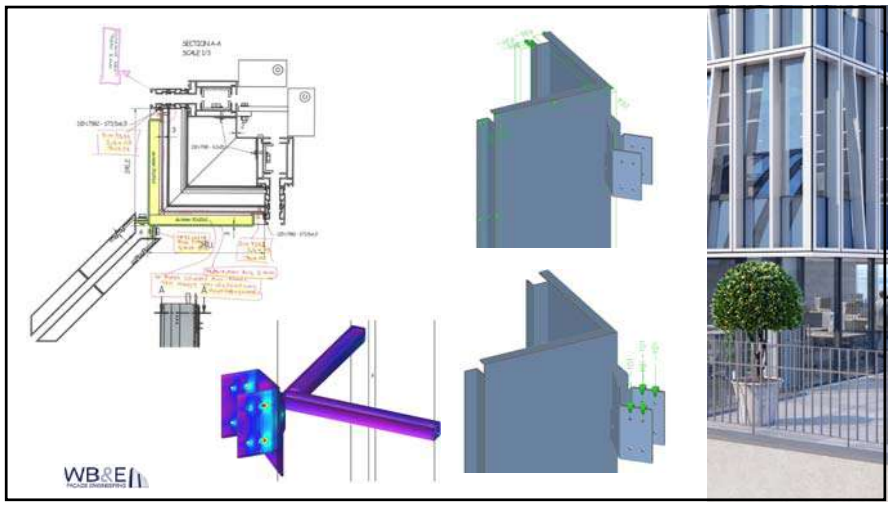

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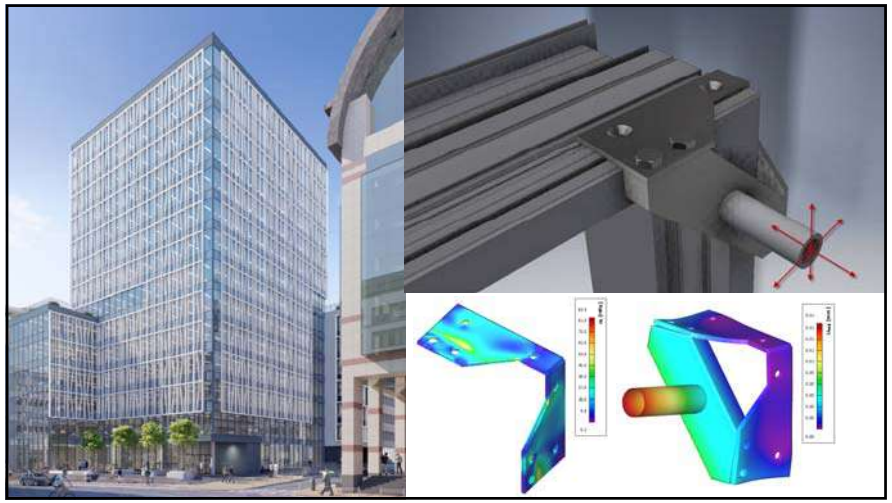

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VERELST
JLG LIFT
VERELST
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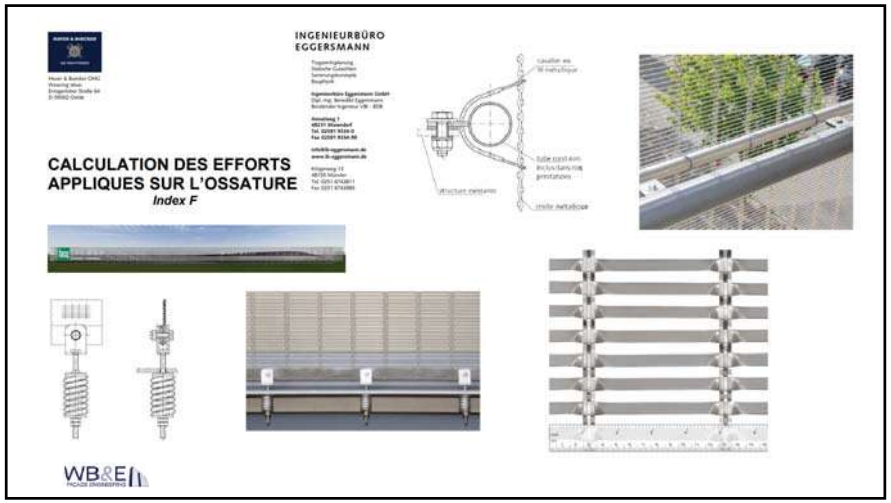
INGENIEURBÜRO
EGGERSMANN
CALCULATION DES EFFORTS
APPLIQUES SUR L'OSSATURE
Index F
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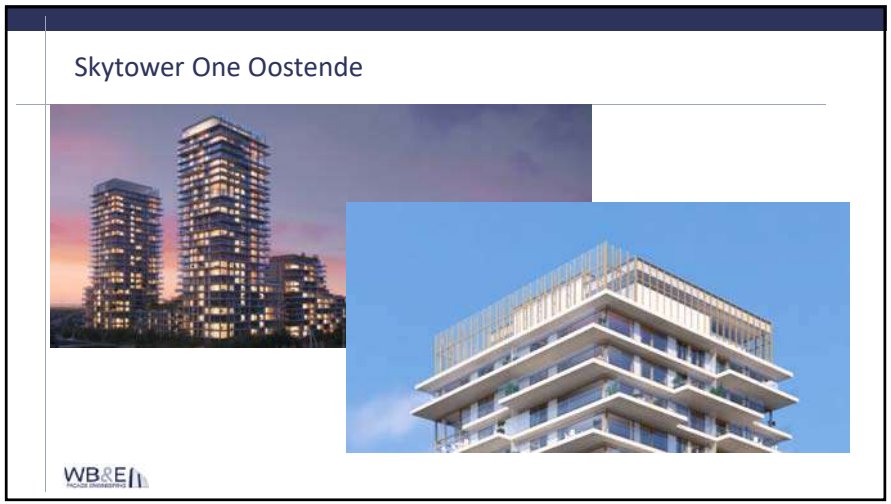
Skytower One Oostende
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## Building Information Modeling (BIM)

- Virtual Construction Modeling
- Virtual reality

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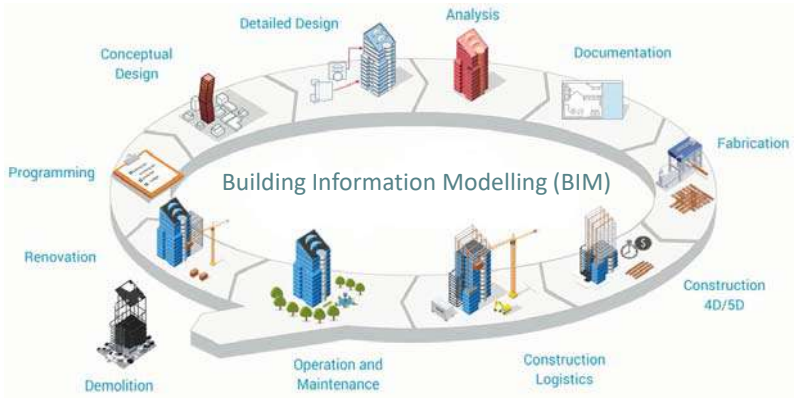


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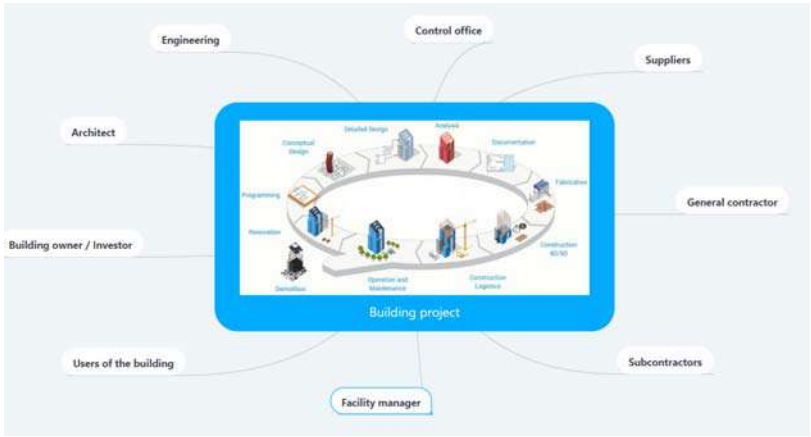


55


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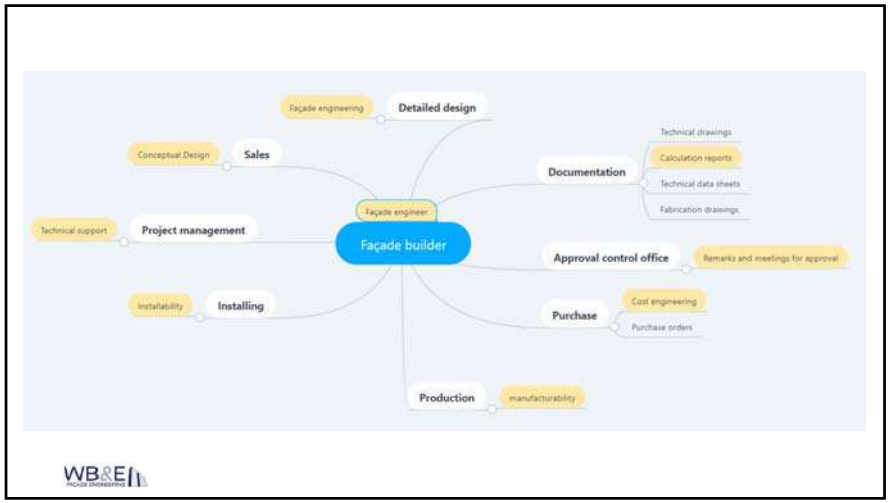
Façade builder
Façade engineer
Façade engineering
Detailed design
Conceptual Design
Sales
Technical support
Project management
Installability
Installing
Documentation
Technical drawings
Calculation reports
Technical data sheets
Fabrication drawings
Approval control office
Remarks and meetings for approval
Purchase
Cost engineering
Purchase orders
Production
manufacturability
WB&E

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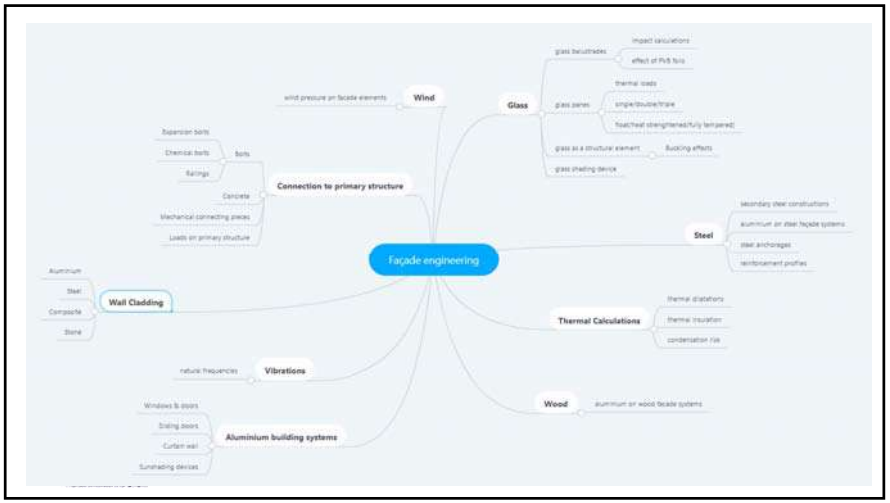
Façade engineering
Wind
Glass
Steel
Connection to primary structure
Wall Cladding
Thermal Calculations
Vibrations
Wood
Aluminium building systems

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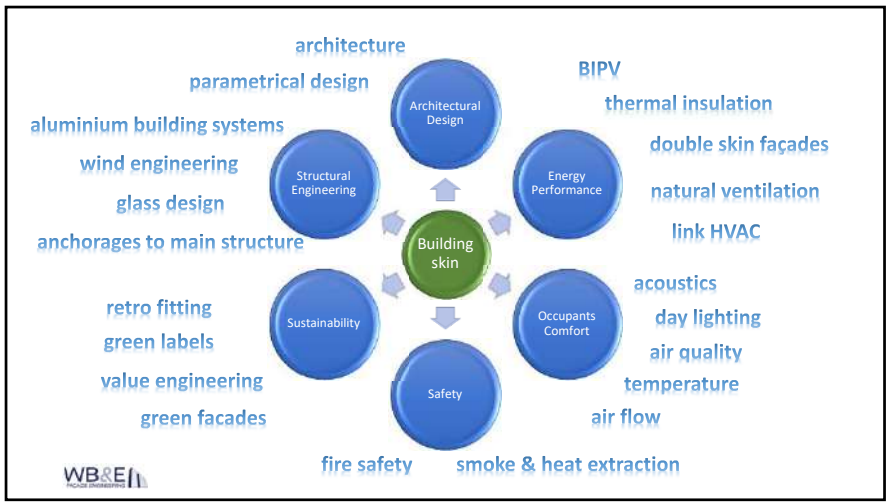
architecture
parametrical design
aluminium building systems
wind engineering
glass design
anchorages to main structure
Architectural Design
Structural Engineering
Energy Performance
Building skin
Sustainability
Occupants Comfort
Safety
BIPV
thermal insulation
double skin façades
natural ventilation
link HVAC
acoustics
day lighting
air quality
temperature
air flow
retro fitting
green labels
value engineering
green facades
fire safety
smoke & heat extraction
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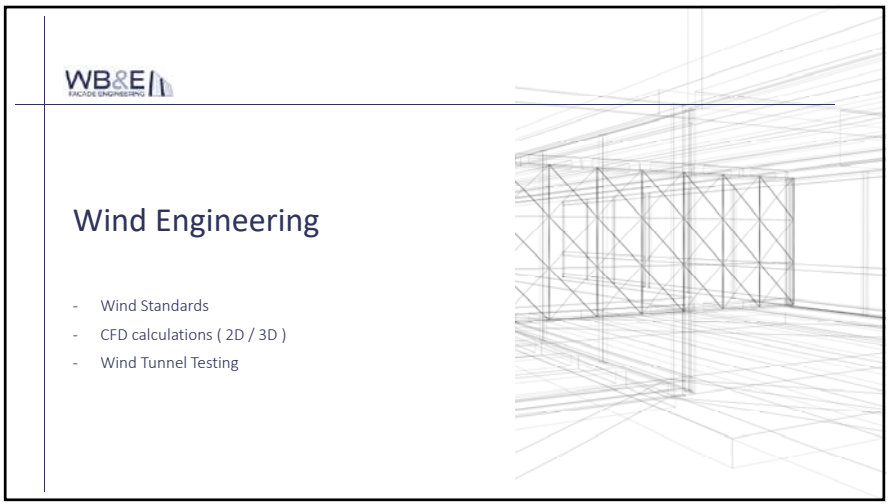
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Wind Engineering
- Wind Standards
- CFD calculations ( 2D / 3D )
- Wind Tunnel Testing

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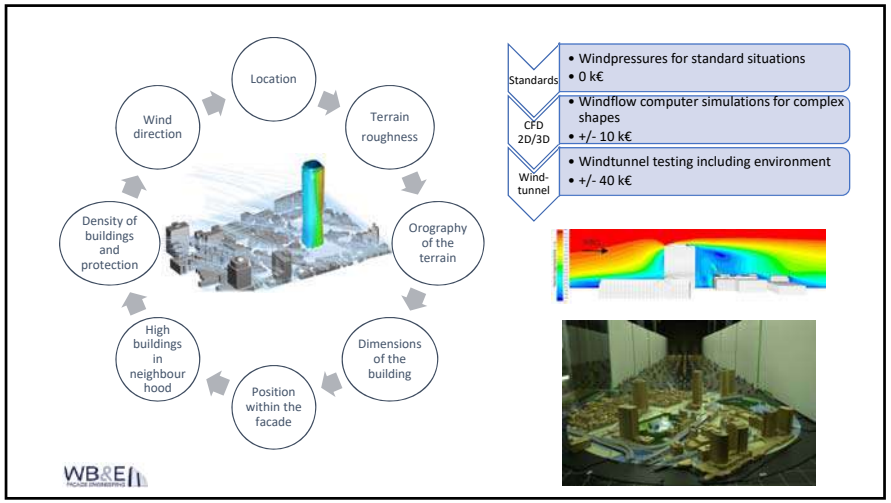
Location
Terrain roughness
Orography of the terrain
Dimensions of the building
Position within the facade
High buildings in neighbour hood
Density of buildings and protection
Wind direction
Standards
• Windpressures for standard situations
• 0 k€
CFD 2D/3D
• Windflow computer simulations for complex shapes
• +/- 10 k€
Wind-tunnel
• Windtunnel testing including environment
• +/- 40 k€
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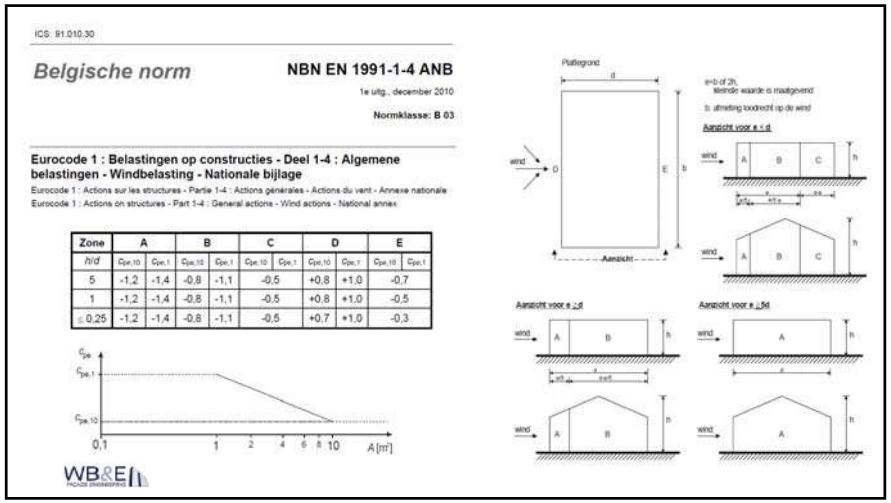
ICS: 91.010.30
Belgische norm
NBN EN 1991-1-4 ANB
1e uitg., december 2010
Normklasse: B 03
Eurocode 1 : Belastingen op constructies - Deel 1-4 : Algemene belastingen - Windbelasting - Nationale bijlage
Eurocode 1 : Actions sur les structures - Partie 1-4 : Actions générales - Actions du vent - Annexe nationale
Eurocode 1 : Actions on structures - Part 1-4 : General actions - Wind actions - National annex
Zone A B C D E
h/d 5 1 ≤ 0,25
-1,2 -1,4 -0,8 -1,1 -0,5 +0,8 +1,0 -0,7
-1,2 -1,4 -0,8 -1,1 -0,5 +0,8 +1,0 -0,5
-1,2 -1,4 -0,8 -1,1 -0,5 +0,7 +1,0 -0,3
0,1 1 2 4 6 8 10 A [m²]
Platgrond
Aanzicht
WB&E

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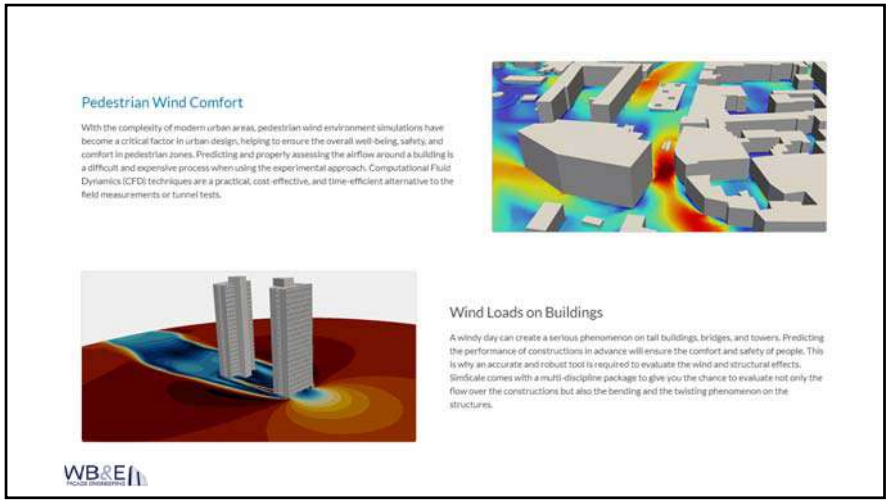
Pedestrian Wind Comfort
With the complexity of modern urban areas, pedestrian wind environment simulations have become a critical factor in urban design, helping to ensure the overall well-being, safety, and comfort in pedestrian zones. Predicting and properly assessing the airflow around a building is a difficult and expensive process when using the experimental approach. Computational Fluid Dynamics (CFD) techniques are a practical, cost-effective, and time-efficient alternative to the field measurements or tunnel tests.
Wind Loads on Buildings
A windy day can create a serious phenomenon on tall buildings, bridges, and towers. Predicting the performance of constructions in advance will ensure the comfort and safety of people. This is why an accurate and robust tool is required to evaluate the wind and structural effects. SimScale comes with a multi-discipline package to give you the chance to evaluate not only the flow over the constructions but also the bending and the twisting phenomenon on the structures.
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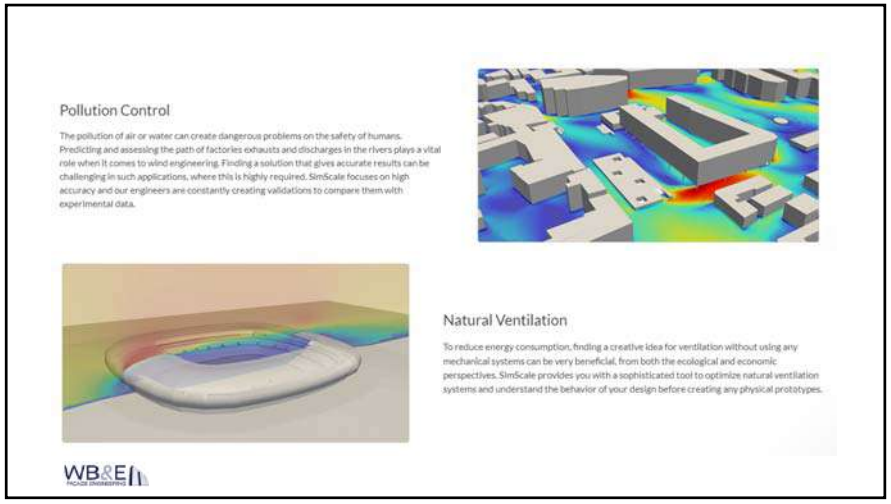
Pollution Control
The pollution of air or water can create dangerous problems on the safety of humans. Predicting and assessing the path of factories exhausts and discharges in the rivers plays a vital role when it comes to wind engineering. Finding a solution that gives accurate results can be challenging in such applications, where this is highly required. SimScale focuses on high accuracy and our engineers are constantly creating validations to compare them with experimental data.
Natural Ventilation
To reduce energy consumption, finding a creative idea for ventilation without using any mechanical systems can be very beneficial, from both the ecological and economic perspectives. SimScale provides you with a sophisticated tool to optimize natural ventilation systems and understand the behavior of your design before creating any physical prototypes.
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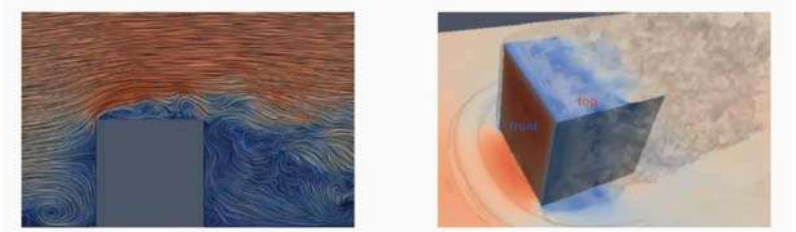


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## Wind Tunnel Testing
Collaboration Wacker Wind Engineering

- Method of wind tunnel testing
  - Test facilities boundary layer Wind tunnel
  - Principles of wind flow creation taking into account
    - Terrain category II
    - Mean horizontal wind velocity
    - Turbulence intensity
    - Spectral density (distribution of gust energy)
    - Integral length scale

**Wind tunnel #1**
(boundary layer wind tunnel):
- cross section: 2.50 x 1.85 m
- speed: 17 m/s
- suburban exposure

**Wind tunnel #2**
(boundary layer wind tunnel):
- cross section: 2.05 x 1.85 m
- speed: 20 m/s
- open exposure

**Wind tunnel #3**
(aeronautical wind tunnel):
- cross section: 1.30 x 1.30 m
- speed: 30 m/s
- uniform flow

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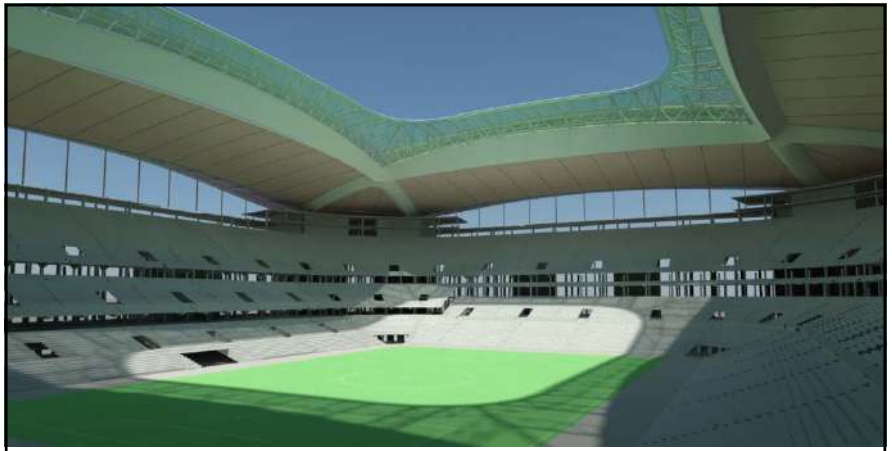

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## Wind Tunnel Testing
Collaboratio Wacker Wind Engineering

- Scale model and similarity laws
  - Translation of 1:350 scale model to full-scale
  - Rigid model
  - Similarity laws
    - Geometrical similarity
    - Similarity of approach flow
    - Similarity of flow around bodies
    - Similarity of dynamic response of structures to wind
    - Similarity of buoyancy flows

Scale 1:350

Test variations:

- ✓ Roof open/closed
- ✓ With/without media screens
- ✓ Media screens in upper and lower position

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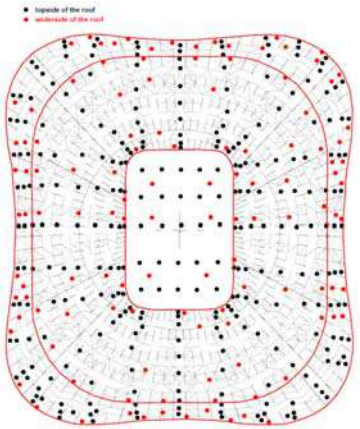
## Wind Tunnel Testing
Collaboration Wacker Wind Engineering

- Measuring points on scale model (roof and facades


About 600 measurement locations along the facade and the roof surfaces

Measurements in 10°- steps

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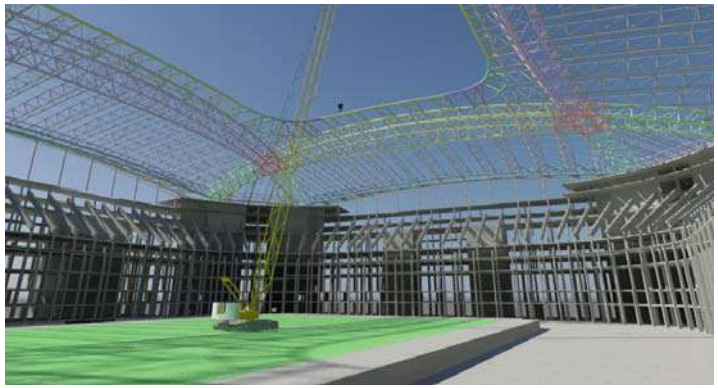

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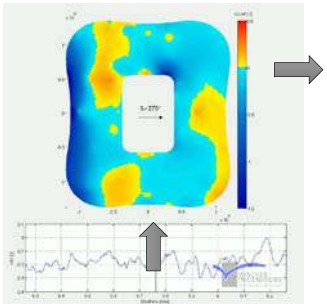
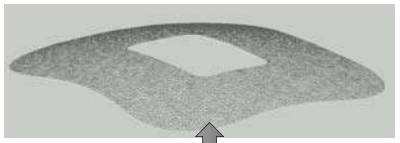
## Wind Tunnel Testing
Meeting Wacker Wind Engineering

- Translation of measured statical wind loads on rigid modelling dynamic properties of the steel roof structure





Input Tractebel = structural parameters of steel roof

- Natural frequencies
- Vibration modes
- Equivalent masses
- Logarithmic decrement of damping

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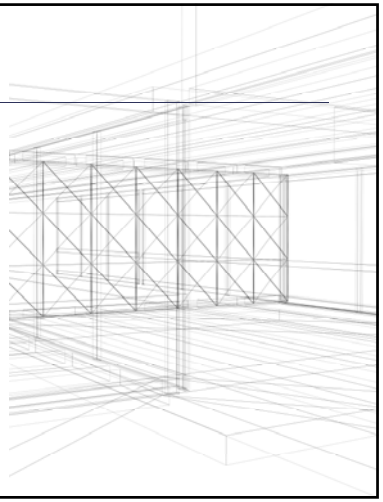
## Aluminium Building Systems

- Curtain walls
- Sliding elements
- Windows & doors
- Sunshading devices



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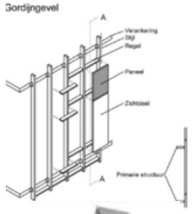
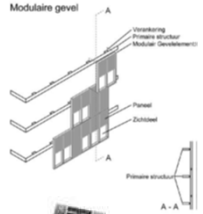
## Curtain wall systems

Stick built curtain wall




Unitized curtain wall




ALUPROF Alumil aliplast

REYNAERS SCHÜCO sapa

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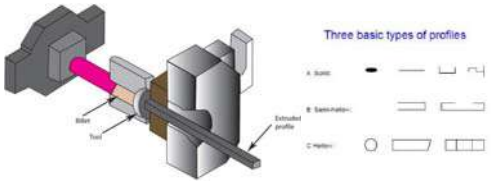
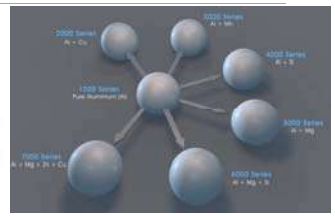
## Aluminium as a construction material → Eurocode 9



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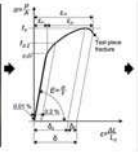
## Aluminium alloys and tempering

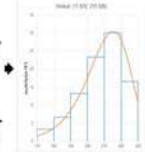
| Alloy EN-AW | Product form | Temper | Thickness $t$ mm 1) 3) | $f_{o}$ 1) | $f_{u}$ 1) | $A$ 5) 2) | $f_{o,haz}$ 4) | $f_{u,haz}$ 4) | HAZ-factor 4) | | BC 6) | $\eta_{p}$ 7) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | N/mm² | | % | N/mm² | | $\rho_{o,haz}$ | $\rho_{u,haz}$ | | |
| 5083 | ET, EP,ER/B | O / H111, F, H112 | $t \le 200$ | **110** | **270** | 12 | 110 | 270 | 1 | 1 | B | 5 |
| | DT | H12/22/32 | $t \le 10$ | 200 | 280 | 6 | 135 | 270 | 0,68 | 0,96 | B | 14 |
| | | H14/24/34 | $t \le 5$ | 235 | 300 | 4 | | | 0,57 | 0,90 | A | 18 |
| 6060 | EP,ET,ER/B | T5 | $t \le 5$ | 120 | 160 | 8 | 50 | 80 | 0,42 | 0,50 | B | 17 |
| | EP | | $5 < t \le 25$ | 100 | 140 | 8 | | | 0,50 | 0,57 | B | 14 |
| | ET,EP,ER/B | T6 | $t \le 15$ | **140** | **170** | 8 | 60 | 100 | 0,43 | 0,59 | A | 24 |
| | DT | | $t \le 20$ | 160 | 215 | 12 | | | 0,38 | 0,47 | A | 16 |
| | EP,ET,ER/B | T64 | $t \le 15$ | 120 | 180 | 12 | 60 | 100 | 0,50 | 0,56 | A | 12 |
| | EP,ET,ER/B | T66 | $t \le 3$ | 160 | 215 | 8 | 65 | 110 | 0,41 | 0,51 | A | 16 |
| | EP | | $3 < t \le 25$ | 150 | 195 | 8 | | | 0,43 | 0,56 | A | 18 |

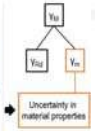
$AlMgSi_{0,5}$

| Alloy | Tempers | Temper designation (EN 515) |
|---|---|---|
| EN - AW 6060 | O | Annealed wrought Alloys |
| | T4 | Solution heat treated & natural aged |
| | T5 | Cooled from an elevated temperature forming operation & artificially aged (precipitation hardened) |
| | T6 | Solution heat treated & artificially aged (precipitation hardened) Press quenching required |
| | T64 | Solution heat treated & artificially aged (precipitation hardened) Under aged to improve formability, bending temper |
| | T66 | Cooled from an elevated temperature forming operation & artificially aged (precipitation hardened) to a higher level of mechanical properties through special control of manufacturing processes. Press quenching required. |

| Werkstof nr. | | Toestand | |
|---|---|---|---|
| EN | DIN | EN | DIN |
| 6060 | AlMgSi0,5 | T4 | F13 zacht |
| | | T64 | F18 koud |
| 3.3206.71 | | T6 | F22 normaal |
| 3.3206.71 | | T66 | F22 hard |





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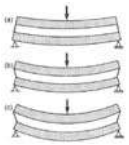
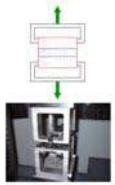
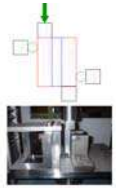
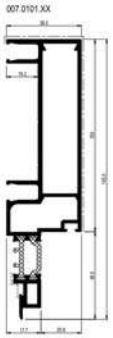
## Thermal break systems



The properties of the insulated profile are determined by the two metals parts and by the characteristics of the insulator.
Generally, only a few types of insulators are used by the manufacturers, mostly made of glass fiber-reinforced polyamide.







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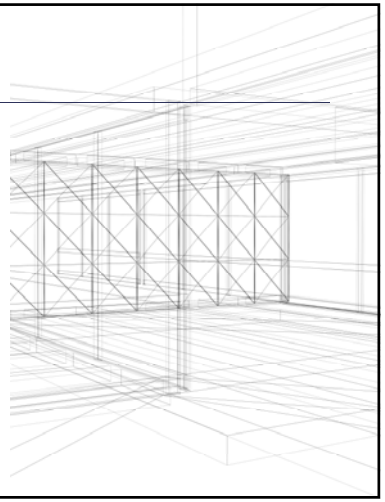
## Glass Engineering

- Glass as a structural element
- Impact behaviour



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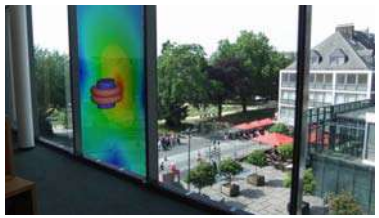

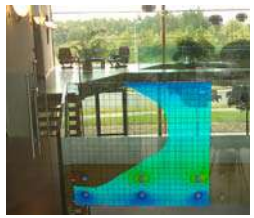

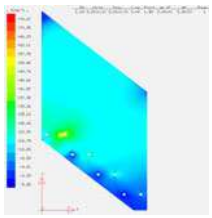

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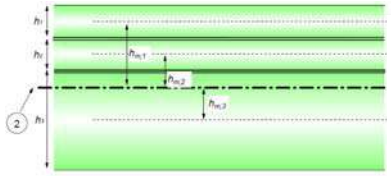

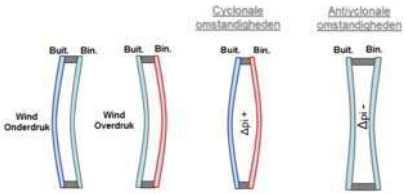


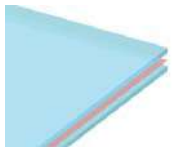

| Berekeningsparameters | | Cyclonale omstandigheden $\Delta p_i +$ | Anticyclonale omstandigheden $\Delta p_i -$ |
|---|---|---|---|
| Buitentemperatuur | $T_{em}$ [°C] = | 10°C | -10°C |
| Binnentemperatuur | $T_{im}$ [°C] = | 20°C | 20°C |
| Zonne-instraling | $I$ [W/m²] | 200 W/m² | 0 |
| Atmosferische druk tijdens het afdichten | $p_a$ [Pa] | 101 325 Pa | 101 325 Pa |
| Druk bij het ogenblik « $t$ » | $p$ [Pa] | 97 500 Pa | 102 500 Pa |
| Temperatuur tijdens afdichten | $T_a$ [°C] | 18°C | 18°C |
| Hoogte van de plaats van installatie | $H$ [m] | 150 m | 0 m |
| Hoogte van de plaats van productie | $H_0$ [m] | 0 m | 150 m |

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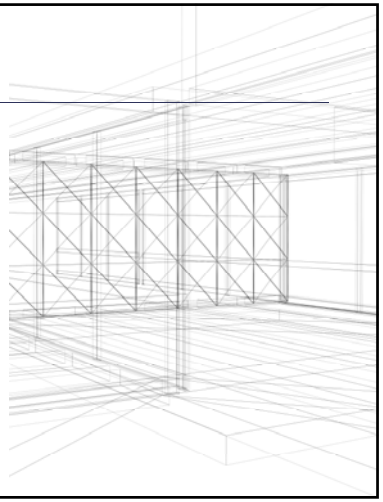
## Achorages to concrete

- Building systems
- Anchorage systems
- Concrete behaviour



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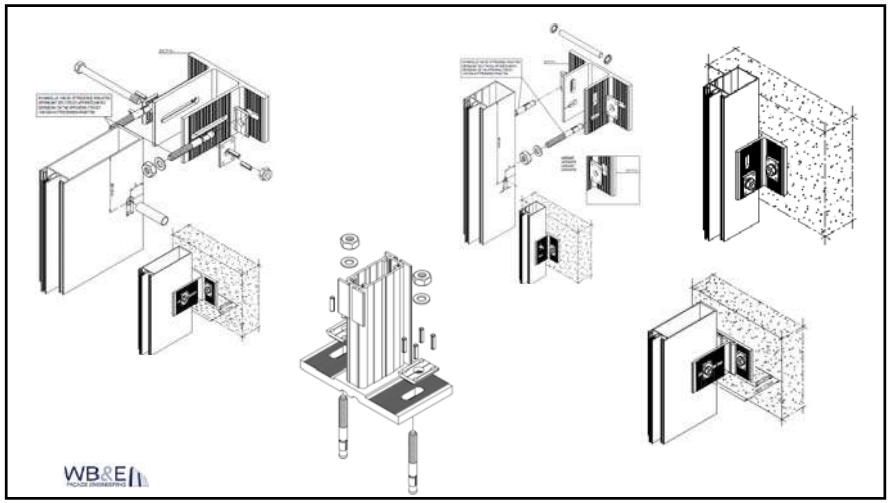


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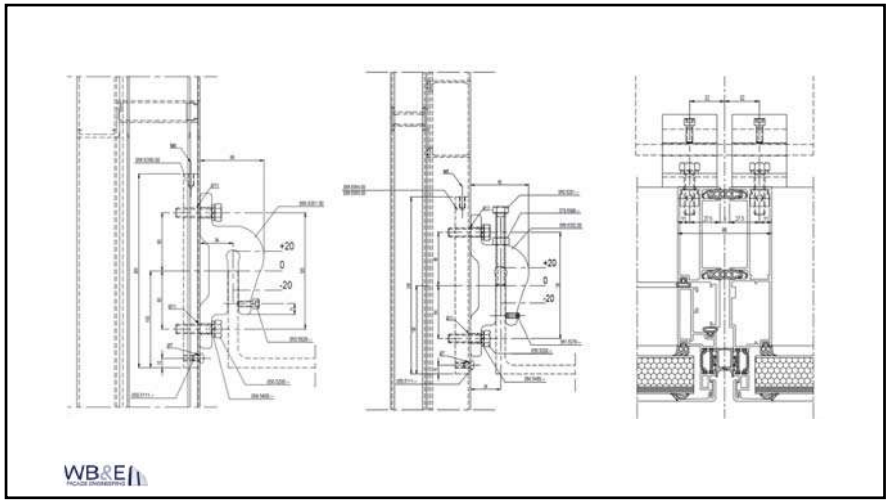


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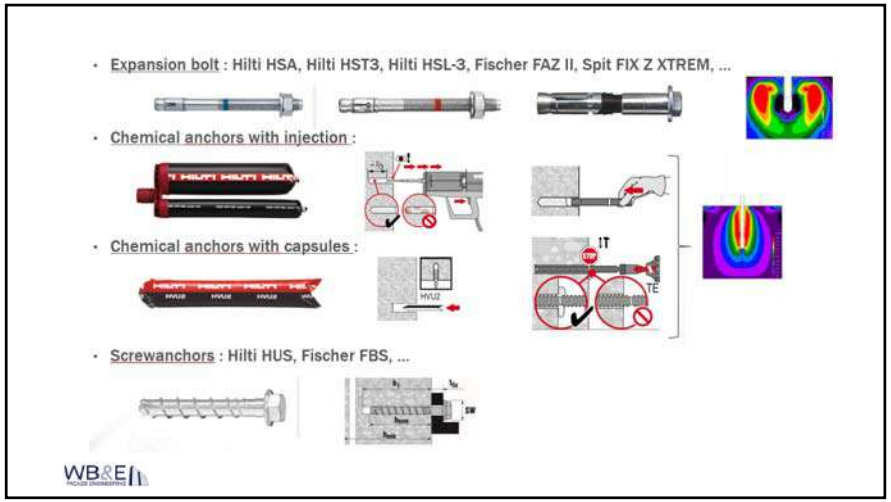


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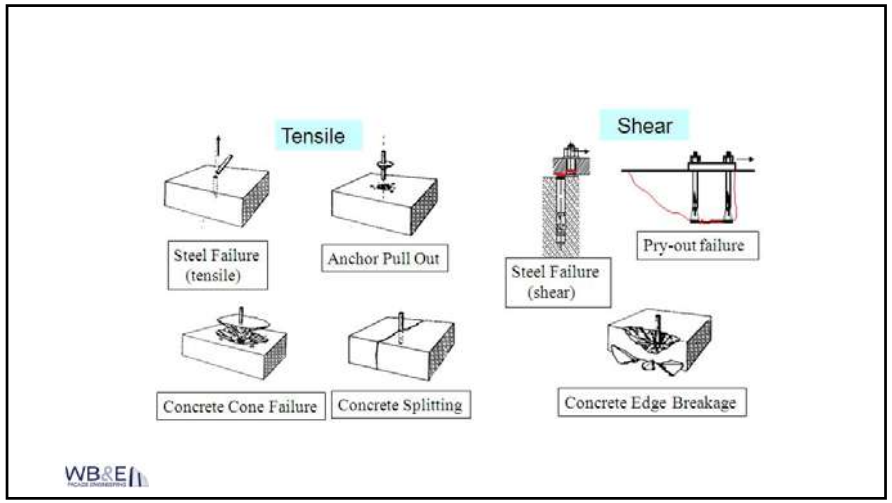


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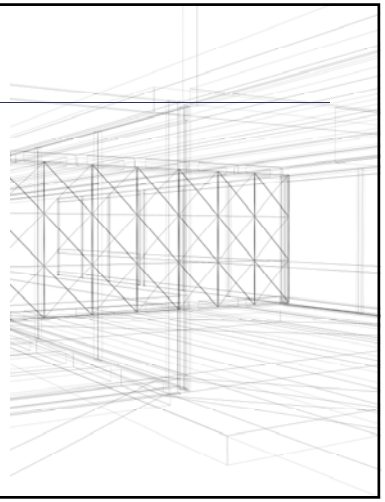
## Future evolutions

- Parametric modeling
- Virtual reality
- 3D printing
- BIM and facility management
- Adaptive facade



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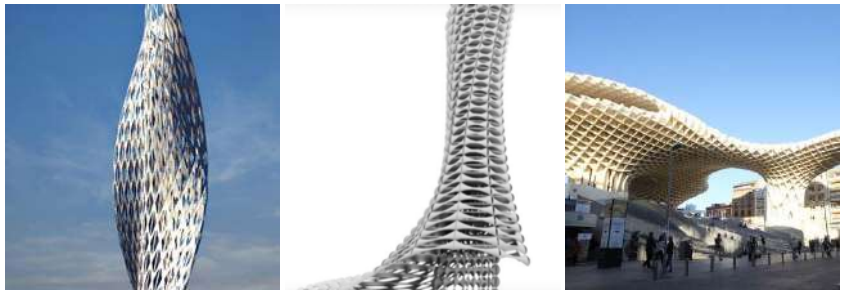

## Parametric design

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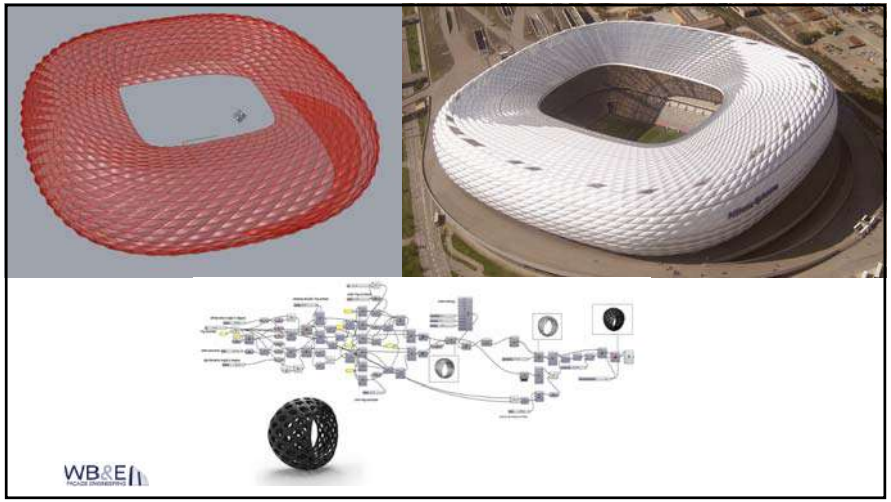

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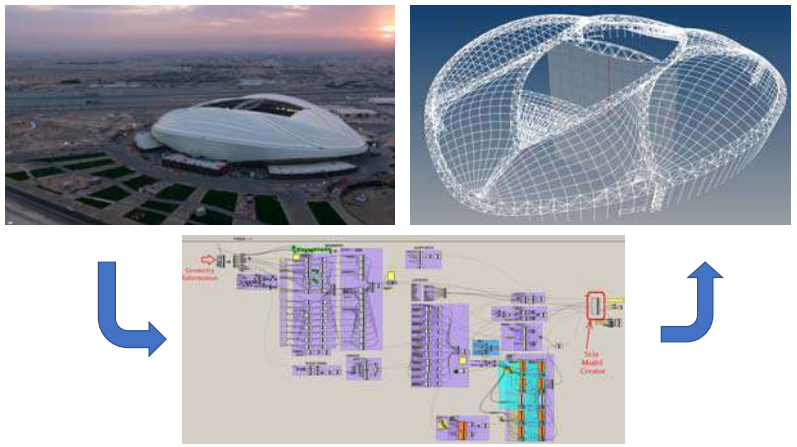

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## Virtual reality

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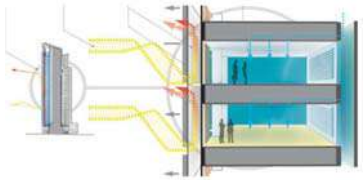
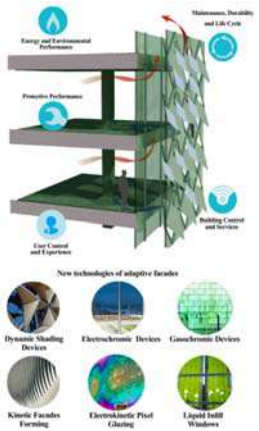
## Adapative facades

The façade is no longer seen as just a static barrier that separates the interior building environment from the external one. In contrast, the façade becomes a dynamic playground to optimise between energy objectives and occupants' wishes



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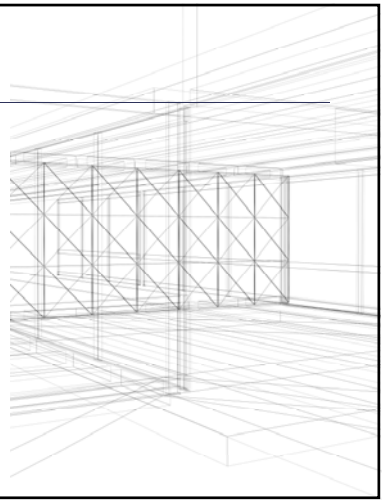
## Facade engineering in Macedonia



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## Facade engineering in Macedonia

- Creation of company in Macedonia : WB&E Facade Engineering
- Local business partner and contact person : Jovica Simovski
- Full support : Prof. D-r. Kokalanov
- Collaboration with University of Skopje for master thesis students
- Training for specialised engineering (aluminium building systems, glass, steel, wind, concrete anchorages, wall cladding systems, …)
- Multidisciplinar team in Macedonia working on international projects
- International website including Macedonian language planned Q4/2019

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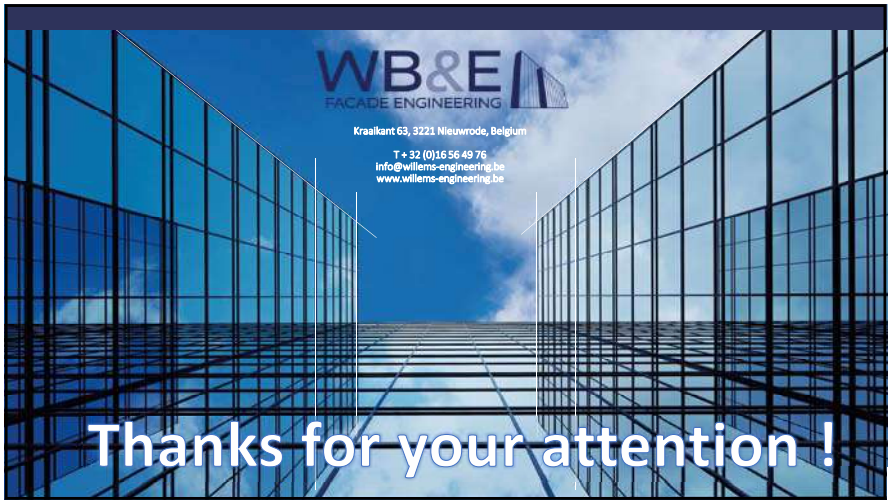


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