Opening the Bonnet

Prof Darren Woolf
WYSINWYG – What You See Is NOT What You Get: Looking inside the Pandora’s Box

Prof Darren Woolf
WYSIWYG
implies a user interface that allows the user to view something very similar to the end result

What You See – Simulation Outputs

WYSIMOLWYG
what you see is more or less what you get - recognizing that most implementations are imperfect

WYSYHYG
what you see you hope you get

YAFIYGI
you asked for it you got it
CONTENTS

• Width and depth of building simulation studies
• Their impact within and on the design process
• Case studies covering
  • Complexities of building physics within simulation
  • Need for planning, attention to detail, scrutiny
  • Good communication supporting an appropriate message
Building Physics: The engineering sciences

Building Physics Science

- Air
- Heat
- Moisture / pollutants
- Light
- Sound
Building physics in practice

Adapted from CIBSE Guide F ‘Energy Efficiency in Buildings’ chapter on concept design
Building Physics skills set is a "toolbox" of methods, models and experiences.

Holistic design and building physics skills

- Structural
- Mechanical & natural ventilation systems
- Architecture
- Facades
- Lighting & daylighting
- Materials

Also:
- Fire
- Wind
- Acoustics
Defining your building simulation services

Performance based design for indoor and outdoor spaces
• Low energy, high comfort levels, high air quality

Environmental modelling
• Dynamic thermal modelling, CFD, daylight

Façade analysis
• Moisture, condensation, thermal bridging, glass performance

Mechanical and natural ventilation systems
• Supply and extract air conditions / configuration
• Configuration and size of openings

Building envelope performance
• Down draughts, overheating risk

EIA, ES
• Wind, sunlight
Bounding your model: Defining geometry and physics
Understanding the relationship between environmental variables

Effect of wind on:
- Local air movement within the garden – effect of walls and terrace lounge
- Air temperatures (mixing)
- Evaporative cooling off water surfaces and features

Effect of air temperatures on:
- Thermal comfort
- Surface temperatures

Effect of the sun on:
- Shading performance
- Surface temperatures – potential radiant effects of surfaces on thermal comfort
- Air temperatures within the roof garden from heated surfaces

Effect of humidity levels on:
- Evaporative cooling performance of still ponds and water features
- Thermal comfort
Using indexes to explain / combine your environmental variables, not bury them

March 1pm: 27°C dry bulb, 51% RH, NW wind

Sense of thermal comfort:
- Very hot: ●
- Hot: ○
- Warm: ▲
- Slightly Warm: ★
- Neutral: ◇
- Slightly Cool: ◥

Air temperatures

Index limits?

Air velocities
Increasing complexity through the design stages

**Simple geometric model (Concept)**
Light–ray tracing (Radiance)

**Advanced droplet model (Scheme)**
CFD
Understanding risk

Advanced droplet model
CFD using a droplet model representing light, medium and heavy rain
Capture of local wind and surface film effects including secondary transport
Improved roof canopy design (integrating performance analysis into design cycle)
Complex facades

Double Skin Façade (DSF) with vents to the side

- Double Glazed Unit (DGU) with air vents to each side (between DSF and office)
- Single Glazed Unit (SGU) with 30mm vertical gaps (apertures between DSF and outside)
Using gut feeling / experienced judgements

<table>
<thead>
<tr>
<th>External Conditions</th>
<th>DSF Conditions</th>
<th>Room Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry-bulb T (° C)</strong></td>
<td><strong>SGU surface T (° C)</strong></td>
<td><strong>Dry-bulb T (° C)</strong></td>
</tr>
<tr>
<td><strong>Wet-bulb T (° C)</strong></td>
<td><strong>DGU surface T (° C)</strong></td>
<td><strong>Mean radiant T (° C)</strong></td>
</tr>
<tr>
<td>Wind speed (m/s)</td>
<td><strong>External Air Change Rate (l/s)</strong></td>
<td><strong>Operative T (° C)</strong></td>
</tr>
<tr>
<td>Direct rad (W/m²)</td>
<td><strong>Global rad (W/m²)</strong></td>
<td><strong>Mech Vent Rate (l/s)</strong></td>
</tr>
<tr>
<td>Diffuse rad (W/m²)</td>
<td><strong>Mean radiant T (° C)</strong></td>
<td>Flowrate out of room through rear transfer grille (l/s)</td>
</tr>
<tr>
<td>Global rad (W/m²)</td>
<td><strong>Operative T (° C)</strong></td>
<td>Flowrate into room through rear transfer grille (l/s)</td>
</tr>
</tbody>
</table>

| * early observations very small ΔT south-facing DSF, afternoon in July |

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WYSINWYG
Devising a simulation strategy
Closer scrutiny using sub-models

Original DTM of 3rd floor

South-facing perimeter office plus DSF

Checking sub model (annulus flow)
- operative temperature and flow directions
  - Extremely complex model with many variables
  - High uncertainty with wind, solar-heat distributions, DSF performance, air movement between internal and external zones
Understanding heat transfer detail within solar transmission

- Relative importance of different elements – contribution to overall heat distribution
Understanding surface detail within the heat distribution

- Each surface has two sides (two sets of surface properties)
- Some surfaces have only incident diffuse radiation (shaded from direct sun), some have direct plus diffuse (in sun patch)
How were the blinds influencing the 3D heat transfer?

- Vertically upward movement in gap between blind and DGU in CFD (not recirculating between these surfaces)
- Limitations of DTM, e.g. only able to attach blind to inside of SGU, HTC?
- How does the heat transfer through a closely coupled blind differ from a far coupled one?
Hand calculations provided an ‘offset’ to better assess predictions and increase confidence overall.
Controlling performance

actuated roof vents

actuated louvres

start of solar gains

starting to partially open

10 min time step recording at hourly intervals

air T just below roof vents
open area
Controlling defaults and time steps

6 min time step recording at 6 min intervals

- Detailed scrutiny exposed excessive switching
- Default / notional air temperature band width used (1K)
- Modified approach for controls strategy
Surface temperature below 0°C, risk of condensation freezing on glazing surface.

Condensation risk zone

1G = single glazed unit
2G = double glazed unit

• Good communication includes simulation outputs that can be easily read and understood
Are you competent for the intended application?

Level 1: Understands how to drive the software and get the results out
Level 2: Successfully implements the standard test models
Level 3: Understands the principles behind the software
Level 4: Good knowledge of the technical manual and/or online help so that non-standard applications can be implemented
Level 5: Clearly explains results at the appropriate level
Level 6: Recognised supervisor on the application of the software
Level 7: Implements user code
Level 8: Recognised expert

CIBSE Guide AM11 ‘Building Performance Modelling’
(2015 – to be published soon)
Some ideas for graduates

• Sensitivity test 1D solar and thermal transmission calculations to better understand heat transfer mechanisms / g-value / U-value formulation at ‘surface property’ level
• Build ‘box models’ to test application, sensitivities and tolerances of software application for ‘single physics’, e.g. long wave radiation
• Examine how your software deals with convective and radiative components of internal heat gains and how the heat is distributed
• Think about statistical positioning of climate data and potential impact of using different targets
Turning **WYSINWYG** into **WYSIWYG**

**Education Education Education!**
(understanding and training)

**Application Application Application!**
(what’s appropriate and practical in budget and time?)

**Defaults Defaults Defaults!**
(watch out for and understand the…)

**Limitations Limitations Limitations!**
(know and explain your…+ assumptions + simplifications)

**Interpretation Interpretation Interpretation!**
(a ‘measured’ sale of your message is a valued one)

**Black Box = Blind Box = Pandora’s Box!**
Any Questions?