ESRU

Report

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Subtask E: Double Skin Facade

ESP-r Modeller Report

Empirical Test Cases

Paul Strachan

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Energy Systems Research Unit
Dept. of Mechanical Engineering
James Weir Building
75 Montrose Street
Glasgow G1 1XJ
Scotland, UK

Email: paul@esru.strath.ac.uk
Tel: +44 (0)141 548 2041
Fax: +44 (0)141 552 5105

http://www.esru.strath.ac.uk

1. Introduction

ESP-r, Version 11.3 of April 2007, was used for the modelling.

ESP-r is Open Source software. Authors are Energy Systems Research Unit, University of Strathclyde, Scotland, UK; Natural Resources Canada; and other groups and individuals.

The program is based on a finite volume approach, with user-selectable timesteps.

The tests reported here are based on the revised Empirical Test Specifications of June 2007.

2. Modelling Assumptions

DSF100_e and DSF200_e cases:

Modelling of the floor of zone 1 (double façade): it is clear in the pictures that the floor is covered with wiring. An assumption was made that this was equivalent to 3mm of insulation on the floor, and surface temperatures on top of this were reported. It is not clear how representative this is of the actual temperatures recorded by the floor sensors. Comparisons are likely to be unreliable.

Modelling of test room floor: this is mostly shadowed from both longwave and shortwave radiation by the fabric ducts. Again, a crude approximation was made that the effect would be similar to a thin (3mm) insulation layer on the floor, and surface temperatures on top of this were reported. It is not clear how representative this is of the actual temperatures recorded by the floor sensors. Comparisons are likely to be unreliable.

Modelling of surface convection in test room: velocities were stated to be less than 0.2m/s; it was assumed that buoyancy-driven convection correlations would be most appropriate.

Test room thermal bridges: these were not included in the model. In a more detailed model, these should be included, making use of estimated linear thermal transmittances calculated for the test room edges. This assumption will lead to an underestimate of the heating load at night time in the test room.

Test room infiltration: this was simply modelled as the measured value at 50Pa pressure difference divided by 20 – a reasonably common approximation. However, a better infiltration model based on wind speed may improve the modelling of air movement.

Test room surface properties: spectral data could not be used. Internal emissivity was set to 0.88 for all opaque surfaces; internal absorptivity for solar radiation was set to 0.34 for opaque surfaces.

Ground reflectivity: Spectral data could not be utilised, so a value of 0.1 was used.

DSF100_e case:
The double façade was modelled as a single zone: it was therefore assumed that the air was fully mixed. Given the likely complex flows that may exist in the façade, the alternative was to use CFD to model the temperature and air velocity distribution. This can be done in ESP-r, and a preliminary model was established, but results have not yet been submitted.

It was assumed that the double façade was perfectly sealed. This is unlikely in practice, but no information on its air tightness was available. It is likely to lead to an overestimate of the internal temperatures.

DSF200_e case:
The double façade was modelled as 3 stacked zones to represent the temperature stratification. Tests in previous projects had indicated that 3 stacked zones were usually sufficient to represent the temperature gradient. Boundaries between the stacked zones were assumed to be essentially massless and fully transparent.

The given pressure coefficients were used (these are likely to lead to the greatest source of uncertainty). A wind speed correction was based on the roof height of 6 m. For open country, the reduction factor was calculated as 0.922.

A discharge coefficient of 0.65 was used for the lower opening (usually supply air) and 0.72 for the upper opening (usually extract air), based on the specification.

3. Modelling algorithms

Solar radiation
ESP-r uses the Perez 1990 anisotropic diffuse sky model for calculating diffuse radiation. Direct and diffuse transmission, glazing absorption and internal zone distribution are calculated separately. Ray tracing is used to allocate the direct solar transmittance to the appropriate internal surface for both the double façade and test room. Diffuse radiation passing through the window is allocated to surfaces not in the same plane as the window based on surface area and absorptivity. After the first bounce, direct radiation is treated as diffuse and added to the reflected diffuse radiation. This is iteratively spread to all internal zone surfaces based on the area and absorptivity (in the case of opaque surfaces) or the absorptances and transmittances (in the case of transparent constructions) until all radiation is accounted for.

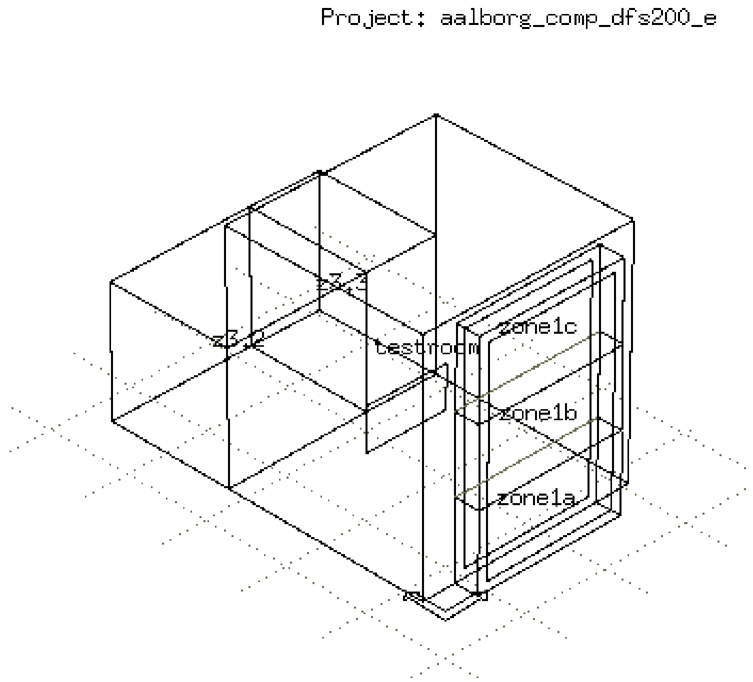
Airflow
For the DSF200_e case, the airflow is modelled using an airflow network approach, which is integrated with the thermal model so that the calculated airflows are based on nodal temperatures from the thermal model (as well as wind-driven pressures), and the resulting predicted airflows are used in the energy balances of the thermal simulation.

The network model is simple in this case – an internal node for each of the 3 stacked zones in the double façade and two external nodes at the top and bottom openings. The top and bottom openings were modelled using the orifice equation with user specified discharge coefficients (0.65 for the inlet at the bottom and 0.72 for the outlet at the top). Opening areas were given as $0.33m^2$ for the bottom and $0.39m^2$ for the top. Pressure coefficients were included as boundary conditions for the openings as given in the specifications. A wind speed reduction factor of 0.922 was included from the 10m wind speed to bring it down to the wind speed at the height of the double façade, which is the reference height for the specified pressure coefficients.

Convection and longwave radiation
These were calculated explicitly both internally and externally for all surfaces. In the case of convection, buoyancy correlations were used for the internal surfaces and an algorithm based on correlations with wind speed and direction was used for external surfaces. For longwave radiation, external radiation was calculated based on estimates of sky and ground temperature, with all vertical surfaces assumed to have viewfactors of 50% to sky and 50% to ground. Internal viewfactors were explicitly calculated for the time-varying internal longwave radiation exchanges for both the double façade and test room.

4. Modelling Options

The building model for the DSF200_e case is shown below. The double façade was modelled as 3 stacked zones to represent temperature stratification.



For the DSF100_e case, the double façade was only modelled as a single zone, with the resulting assumption that the air inside is fully mixed.

Glazing properties: as input, ESP-r requires the optical properties (transmittance and layer absorptances) at angles of incidence of 0, 40, 55, 70 and 80 degrees. For the single and double glazed units in the double façade, these were obtained using WIS for the glazings given in the specification, using the supplied spectral values. The normal incidence values were essentially the same as those given in the specifications. For the single glazing the following values were used:

Angle	**0**	**40**	**55**	**70**	**80**
Solar transmission	0.763	0.741	0.690	0.550	0.323
Solar absorption	0.161	0.175	0.184	0.191	0.180

For the double glazed unit, values were as follows:

Angle	**0**	**40**	**55**	**70**	**80**
Solar transmission	0.532	0.513	0.462	0.331	0.163
Solar absorption outer	0.103	0.111	0.117	0.119	0.110
Solar absorption inner	0.114	0.119	0.120	0.114	0.089

Framing: this was lumped and modelled as a separate surface.

Thermal mass: this was represented as additional surfaces inside the test room. The ventilation system has a stated mass of 750 kg mass. Not all this is directly linked to internal air (e.g. internal fans in ductwork etc). In the absence of other information, it was assumed that 375 kg is “accessible” to the room air.

Rooms to rear of testroom: measured 10 minutely temperatures were used as set points for these rooms so the air temperature in the simulation corresponded to the measured values.

Simulation timestep: 10 minutes, to coincide with the provided climate and temperature data which was used for the boundary conditions. Results data were post-processed to provide hourly averages.

5. Modelling Difficulties

ESP-r does not output the incident direct and diffuse or the solar altitude in the results file. Instead, the simulation trace facility was turned on, and the required data extracted by processing the output.

6. Software Errors Discovered and/or Comparison Between Different Versions of the Same Software

None.

7. Conclusions and Recommendations

Results indicate that the night time heating load is under-predicted for the test room. This may be due to the fact that thermal bridges were ignored. Further simulations should be run to check this. It may be a good idea to model the thermal bridges with specialist software and provide the information to all participants (as was done with the test cell experiments at EMPA for the subtask C on shading/daylight/solar interaction). A sensitivity study could also be done on the infiltration in the test room to see if this has a significant

8. References

WIS: Window Information System, available from http://www.windat.org/wis/html/index.html.