ENERGY AND THERMAL ANALYSIS OF GLAZED OFFICE BUILDINGS USING A DYNAMIC ENERGY SIMULATION TOOL

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ABSTRACT

Highly glazed buildings are often considered to be airy, light and transparent with more access to daylight than traditional buildings, but their energy efficiency is often questioned. This article deals with energy and indoor climate simulations of single skin office buildings in Sweden using a dynamic energy simulation tool. Different building alternatives were studied with 30%, 60% and 100% window area. The following parameters were varied: the building's orientation, the plan type, the control set points and the façade type.

The chosen simulation program was shown to be very useful, but some improvements would be of interest. Unless the design of a highly glazed façade is very well done there is a high risk for a poor energy and indoor climate performance of the building. The methods and the results of the parametric studies are discussed.

INTRODUCTION

Modern office buildings have high energy savings potential and potential for indoor climate improvements. During the nineties many office buildings with single and double skin glass facades were built. Single skin glazed office buildings are considered to be airy, light and transparent with more access to daylight than traditional buildings, but their energy efficiency is often questioned. In order to improve the building's performance, double skin facades have been introduced. Today the knowledge of function, energy use and visual environment of highly glazed office buildings for Scandinavian conditions is insufficient. Therefore, a project was initiated to gain knowledge of possibilities and limitations with glazed office buildings in Scandinavian climates as to energy use and indoor climate (www.ebd.lth.se). This means further development of calculation methods and analysis tools, improvement of analysis methodology, calculation of LCC, compilation of advice and guidelines for the construction of glazed offices and strengthening and improving the competence on resource efficient advanced buildings in Sweden.

The choice of the envelope type is crucial for the energy efficiency and the indoor climate. The energy use for different glazed building alternatives may vary more than for buildings with traditional façades since the glazed alternatives are particularly sensitive to the outdoor conditions. The first part of this project has meant establishing a reference building with different single skin glazed alternatives, choosing simulation tools and carrying out energy and indoor climate simulations for these alternatives (Poirazis 2005). For the simulations the dynamic energy simulation tool IDA ICE was chosen.

METHODS

A virtual reference building was created, a building representative, as to design, energy and indoor climate performance, of Swedish office buildings built in the late nineties (SCB 2001, REPAB 2003). The design of the building was determined by researchers from the Division of Energy and Building Design, architects and engineers from WSP and Skanska. First, detailed performance specifications for energy and indoor climate were established and then typical constructions were determined for the reference building. System descriptions and drawings were prepared. The building was approved by a reference group. Finally a validation of the simulated performance of the building showed that the performance specifications were fulfilled.

For this building a parametric study of energy use and indoor climate was carried out, where in the simulations the building construction, HVAC system and control system were described in great detail. The building's orientation, plan type, control set points, façade elements (window type and area, shading devices, etc) were changed while other parameters such as the building's shape, the occupants' activity and schedules, etc were kept the same. A sensitivity analysis based on the simulated alternatives was carried out regarding the occupants' comfort and the energy used for operating the building.

The simulation tool used was IDA ICE, a dynamic energy simulation tool, used by consultants and researchers in Sweden, Finland and Switzerland

(Bring 1999, Equa 2002) for advanced energy and indoor climate analysis. Validation tests have shown the program to give reasonable results and to be applicable to detailed buildings physics and HVAC simulations (Acherman 2000 and 2003). In order to analyze the large amount of output data from the simulations a post processor in MS Excel was developed. The output of IDA simulated alternatives will be stored in a database which will be used as a building performance tool.

DESCRIPTION OF THE BUILDING MODEL

Description of the reference building

The reference building is a 6 storey high building (see figure 1) with a height of 21m, a length of 66 m and width of 15.4 m. The total floor area is 6177m^2. The room height is 2.7m and the distance between floors is 3.5m. Two plan types were assumed for the simulations; cell and open plan.

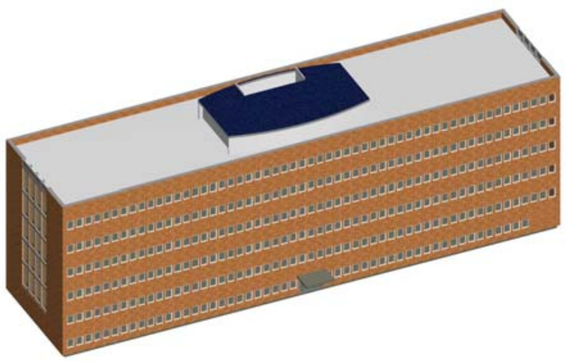

Figure 1. View of the glazed reference building, where the glazed area is 30 % of the façade area.

In order to reduce the simulation time in IDA, but still be able to analyse the indoor climate for individual rooms, the number zones was reduced to 11 per floor for the cell type and to 7 per floor for the open plan type (see figure 2).

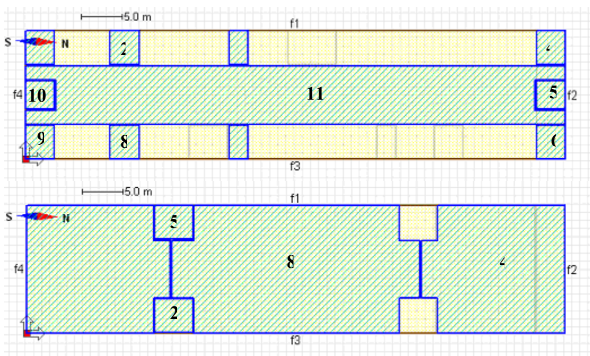

Figure 2. View of cell and open plan type (IDA input).

However, in order to calculate the total building energy use each zone type was multiplied with the number of the identical ones in the entire building (see table 1).

Table 1
Zone description for a floor.

ZONE NUMBER	ZONE TYPE	ZONE REPETITION
1, 4, 6, 9 (cell)	Corner office rooms	1 (each floor)
2, 8 (cell)	Double office rooms	7 (each floor)
3, 7 (cell)	Single office rooms	14 (each floor)
5, 10 (cell)	Meeting rooms	1 (each floor)
11 (cell)	Corridor	1 (each floor)
1, 4 (open)	Corner zones	1 (each floor)
8 (open)	Intermediate zone	1 (each floor)
2, 5 (open)	Meeting rooms	2 (each floor)

The chosen values for the thermal transmittance of the building elements, are representative for the nineties and corrected for thermal bridges (see table 2). Thermal bridges can be included in IDA as an additional heat loss factor. However the most straightforward way is to make a separate calculation of the additional heat loss caused by the thermal bridges and then correct the U-values for the individual building elements in IDA. This was done using a three dimensional heat conductance program.

Table 2
Thermal transmittance of building elements.

BUILDING ELEMENT	U value (Wm^{-2}K^{-1})
External wall (long façade)	0.32
External wall (short façade)	0.25
Internal walls	0.62
Roof (above 6th floor)	0.18
Ground floor	0.32
Intermediate floors	1.74

As already mentioned, the glass area of the simulated building alternatives varies (30%, 60% and 100% of the façade area). For the 30% glazed alternatives a triple clear pane window with a venetian blind in between two of the panes was assumed. For the 60% and 100% ones, however, several alternatives were generated (see table 3). The first alternative is the same as for the 30% alternative, which was chosen only to enable a first comparison. A real building would have better glazing, therefore different alternatives with lower U-values and solar transmittance (g) were studied. The two first alternatives have intermediate venetian blinds, alternative 3 – 5 internal venentian blinds, alternative 6 internal screen and the last alternative external louvres (see also GENERATION OF GLAZED ALTERNATIVES).

Table 3
Glazing and frame properties for the 30% and 60% glazed alternatives.

BUILDING ALTERN.	$U_{glazing}$ (W/m^2K)	g	$U_{eff..}$ (W/m^2K^1)	$g_{eff.}$
1	1.85	0.69	1.65	0.30
2	1.14	0.58	1.08	0.22
3	1.14	0.35	1.07	0.28
4	1.11	0.22	1.04	0.22
5	1.14	0.58	1.08	0.47
6	1.14	0.35	0.92	0.19
7	1.14	0.35	1.14	0.2

The effective values are with the shading devices on (100%). The thermal transmittance of the frame is 2.3W/m^{2}K when triple clear glazing is used (30% glazed alternative and the first of the 60% and 100%) otherwise it is 1.6W/m^{2}K.

Occupancy

For the reference building it was assumed that 80% (considered to be a typical value) of the (theoretical) occupants are present in the rooms during working hours. The occupants' schedule is from 08:00 -12:00 and 13:00 – 17:00 for the offices and from 10:00 – 12:00 and 13:00 – 15:00 for the meeting rooms every workday. The occupancy, however, drops during Christmas (by 50%) and summer vacations (by 50% during June and August and by 75% during July). The activity level was assumed to be 1 met (108 W/occupant) for occupants sitting and reading. Finally the occupant's clothing was assumed to be 1clo (trousers, long-sleeve shirt, long-sleeve sweater, T-shirt) during winter and 0.6 clo (trousers, long-sleeve shirt) during summer.

The total number of occupants differs for the open and cell plan type. For the cell type the "theoretical" number of occupants is 454 and the "practical" one (80% occupancy for the offices and 40% for the meeting rooms) is 319. For the open plan type, there was assumed an increase of 20% for the office space, while the density of the meeting rooms was kept the same. This gives a total "theoretical" number of occupants of 590 and a "practical" one of 395. The open plan has more meeting rooms than the cell type. The occupant's density for the cell type plan is 18m^2/employee and for the open plan type is 15.5m^2/employee. The total increase of the cell type office occupant's density is 15%.

HVAC strategy

For the meeting rooms a VAV (variable air volume) CO_2 control is assumed. For the cell type, it is assumed that the air is supplied in the offices and extracted from the corridors. For the offices there is a CAV (constant air volume) control supplying 10l/s of preheated outdoor for each person. For the open plan it is assumed that the air is supplied and exhausted from the office space (since there is no separation between offices and corridors). The supply air for each person is assumed to be 7l/s for the office space (CAV control).

The infiltration rate including some window airing is assumed 0.1ach. The heat recovery efficiency was set to 60%. The central air handling unit (AHU) is on from 06:00 till 20:00 during weekdays and from 8:00 till 17:00 during weekends. The only way the infiltration rate can easily be included in the IDA simulations, is to add it to the mechanical air flow. Then the heat recovery efficiency had to be corrected, as there is no heat recovery on the air infiltration. Alternatively leakage paths and wind pressure coefficients can be specified and then IDA calculates the natural ventilation

Control set points

Three control set point (VVS 2000) intervals for the indoor temperature were chosen for the simulations of the reference building (see Table 4). The normal control set points are considered the standard (reference) case (Swedish practice in modern offices). However, the two other control set points can provide useful information concerning the temperature variation with the energy use, the perception of thermal comfort and the occupants' productivity. For the water radiators was used a proportional and for the cooling beams a PI control.

Another parameter changed for in the three different control set points is the artificial light set point for the workplace. For the strict control it is assumed that the lights are switched on for the occupants' schedule, regardless of the amount of daylight inside the offices. For the normal and poor control set points, however, there was assumed a set point of 500lux and 300lux respectively at the workplace. IDA provides a simple model of daylight availability. The main reason that these set points were assumed is to calculate the savings of the electricity for artificial lighting for different control set points, glazing, shading devices and proportion of glass in the building.

Regarding solar shading, it was assumed that the movable shading devices are fully closed, when the incident radiation inside the glass exceeds 100 W/m^2.

None of the controls for shading is optimal with regard to use of daylight or use of electricity for lighting, but might be appropriate for a conventional building. It is difficult to implement a more advanced shading control in IDA.. The best alternative is probably to first carry out a separate calculation with a daylight model and then to find a way of taking into account the results in the IDA simulations.

Table 4
Control Set points for the glazed alternatives.

CONTROL SET POINT	**MIN. TEMP. (ºC)**	**MAX. TEMP. (ºC)**	**DAYLIGHT AT DESK (lux)**
Poor	21	26	Set points
Normal	22	24.5	Set points
Strict	22	23	Schedule

GENERATION OF GLAZED BUILDING ALTERNATIVES

For the 30% glazed building 18 alternatives were simulated. The building construction was kept the same, while three orientations (short façade facing the NS, the EW and NS45), three control set points (strict, normal and poor) and two plan types (cell and open) were studied in order to analyse their influence on the building's performance.

For the 60% and 100% glazed alternatives 7 different window constructions (commercially available) were chosen (for each construction different alternatives were generated). The remaining building construction was kept the same (as for the 30% glazed alternative). Each one of them was simulated for a cell and open plan type office building and for strict, normal and poor control set point. In total 84 alternatives were simulated. The first building alternative works like a "bridge" between the 30% and 60% glazed buildings. The $U_{glazing}$ and U_{frame} values were kept the same (triple clear pane window) in order to study the impact of higher glazing area on the energy use and the occupant's comfort. The number and type of panes, the type and positioning of shading devices, etc, are also the same as for the 30% glazed building.

In the second building alternative the type of window changed (lower $U_{glazing}$ and U_{frame} values) in order to get a more realistic solution for a glazed building. The new glazing is a triple pane (2+1). The type and position of the shading devices stays the same.

In the third alternative the triple glazing unit is replaced by a double one with the same U value. The solar factor (g value) is decreased however to 0.354 from 0.584. The intermediate venetian blinds are replaced by internal ones (the properties of the blinds remain the same). This window type was chosen as a typical alternative used for a 60% glazed building.

In the forth alternative the U value of the window remains the same, while the solar factor (g value) is decreased to 0.277 in order to investigate its impact on the cooling demand. In the fifth alternative the U value of the window remains the same, while the solar factor (g value) increases up to 0.584. The number of panes, the position and type of shading devices remain the same. These two cases were selected in order to further investigate the influence of g value on the heating and cooling demand. Additionally, since the glazing and frame properties are the same with the second alternative, it is possible to investigate the influence of the position of the shading devices on the energy use and thermal comfort.

In the sixth alternative venetian blinds are replaced by internal screens. The window construction is identical with the third alternative, since this is considered to be more often used. With this alternative it is possible to investigate the influence of different type of shading device on the energy use and indoor environment.

In the last alternative the internal screens are replaced by fixed external louvers. The window construction is again identical with the third alternative. The louvers' construction is explained in detail below.

RESULTS AND DISCUSSION

Description of the outputs

The parametric studies were carried out at a building and at a zone level. The performance parameters examined in this report are:

- Energy use (for heating, cooling, lighting, pumps and fans, etc)
- Weighted (monthly average) air temperatures for the entire working area. For the cell type office building, only offices and meeting rooms were included in the calculations. The corridor was excluded since the impact on the occupants comfort is limited. However, for the open plan type the whole area was considered for the calculations since all this area is used as working space.
- Number of hours between certain (weighted) monthly average air temperatures for the entire working space: This output is more a quantitative indicator compared with the previous output since there is not any information related to the variation of the indoor temperatures during the year.
- Weighted monthly average PMV: The Predicted Mean Vote is a qualitative indicator of the perception of thermal comfort (ASHRAE 1997). This factor basically shows whether the controls are proper or not for certain occupancy, since it provides information all year round.
- Number of working hours for certain average PPD: In a similar way an average Predicted Percentage of Dissatisfied (PPD) is the sum of the PPD of each occupant multiplied with the

number of occupants in each zone and the number of the identical zones divided with the number of occupants. This output is more a quantitative indicator for the perception of thermal environment in the working space.

- Productivity: This parameter connects the perception of the indoor environment with the efficiency of the occupants. Too high or too low air temperatures in a room result in production losses from workers. For mean air temperatures between 20 and 25 °C no work is regarded as lost. Above and below these limits experiments show that the average loss in performance can be estimated to be 2% in performance per degree (Wyon 2000). This parameter is not presented here.
- Indoor Air Quality: monthly average CO_2 content and air humidity (not presented here).

The energy use, the average mean air and temperatures, the perception of thermal comfort, the indoor air quality and the productivity are examined and compared on a building level. The mean air and directed operative temperatures and the perception of thermal comfort in detail (PPD, PMV, directed operative temperature, etc) are examined on a zone (room) level. Due to the large amount of output, the presentation of the results is done selectively.

Energy use

The impact of orientation on the 30% glazed building's energy use is small (see table 5). When the short façade faces the East-West, the energy use for cooling decreases by 2kWh/m^{2}a. The impact of the plan type (when comparing the C-NS45-normal and O-NS45-normal) on the heating and cooling demand is obvious. Due to the increase of occupant's density the internal loads of the open plan are higher than the ones of the cell type. This increases the cooling demand and decreases the heating one.

Table 5
Energy use for 30% glazed alternatives, where:
C, O: cell or open plan type
NS, NS 45, EW: short façade facing the North-South, NS45 (North-west – South-east) or East –West
Strict., normal, poor: the control set points

30% GLAZED ALTERNAT.	SPACE HEATING (kWh/m^{2}a)	COOLING (kWh/m^{2}a)	TOTAL (kWh/ m^{2}a)
C-NS-normal	52	12	123
C-NS45-strict	56	20	136
C-NS45-normal	52	11	123
C-NS45-poor	47	7	113
C-EW-normal	52	10	122
O-NS45-normal	45	17	127

The total energy use is slightly higher for the open plan type. Finally, the impact of control set points on the energy use is shown when comparing the alternatives C-NS45-str, C-NS45-nor and C-NS45-poor. Although the minimum allowed temperature for the strict and normal set point is the same (22ºC), there is an increase of heating demand for the first one, since the strict set points (narrow temperature variation) reduce the possibility of storing heat (thermal mass). The energy use for the poor control set point is even lower since the minimum allowed temperature drops to (21ºC). The impact of energy demand is even higher in cooling, since the maximum allowed temperatures of the different control set points (23ºC, 24.5ºC and 26ºC) decrease the energy use up to 13kWh/m^{2}a (difference between strict and poor control set point).

Table 6
Energy use for 60% glazed alternatives.

60% GLAZED ALTERNAT.	SPACE HEATING (kWh/m^{2}a)	COOLING (kWh/m^{2}a)	TOTAL (kWh/ m^{2}a)
C-NS45-nor (1)	72	20	151
C-NS45-nor (2)	50	24	133
C-NS45-nor (3)	54	18	131
O-NS45-nor (3)	46	22	133
C-NS45-nor (4)	56	13	129
C-NS45-nor (5)	49	36	144
C-NS45-nor (6)	54	18	131
C-NS45-nor (7)	59	7	126

As already explained the first 60% glazed alternative was chosen only for a cross comparison with the 30% glazed building. As expected, the total energy use increases dramatically (28kWh/m^{2}a) (see table 5 and 6). The increase of heating demand in this case reaches 20kWh/m^{2}a. When the thermal transmittance of the window is reduced, the total energy use is decreased by 18kWh/m^{2}a. As can be expected, the highest energy savings come from the space heating. By reducing the solar factor in the third alternative and replacing the intermediate blinds by internal ones, the energy demand for cooling is slightly increased and the energy demand for heating is slightly increased. The total energy use drops 2kWh/m^{2}a. A further decrease of the solar factor (fourth alternative) causes exactly the same results (total decrease of 3kWh/m^{2}a compared with the third alternative). When increasing the solar factor (still using internal blinds) in the fifth alternative, keeping the rest of the parameters the same, the energy use for heating decreases 5kWh/m^{2}a, while the energy for cooling is increased 18 kWh/m^{2}a (compared with the third alternative). The total energy use is increased 12kWh/m^{2}a. The only difference between the second and fifth alternative is the position of the venetian blinds. The intermediate blinds (second alternative) give an effective solar factor of 0.22 while the internal ones (fifth alternative) give a factor of 0.47. As expected, the intermediate blinds are better for the possible overheating problems since the cooling demand is 11kWh/m^{2}a lower. The heating demand on the other hand is slightly increased in the second alternative (1kWh/m^{2}a). By replacing the internal blinds of the third alternative by internal screens (sixth alternative), the effective solar factor is slightly decreased. At the same time, however, the effective thermal transmittance also drops to 0.92 W/m^{2}K^1 (from 1.08 W/m^{2}K^1). This results in a slight decrease of heating and a slight increase of cooling demand. Finally in the seventh alternative, the internal blinds of the third alternative were replaced by external fixed horizontal louvers. In this case the solar factor was calculated for each month and a monthly average g value was inserted in IDA, as IDA calculates a yearly g value. This in order to better approximate the reality. As expected, using external shading devices the cooling demand drops and the heating demand increases. The total energy use is the lowest of the seven alternatives. However, since the properties of the shading devices were calculated in a different way, it is preferred to pick the forth alternative as the most energy efficient one.

The third alternative was picked as a typical case for comparisons of the plan types (C-NS45-nor (3), O-NS45-nor (3)). As in the 30% glazed alternatives, the heating demand of the cell type is higher than the one of the open plan, and the cooling demand is higher. The total energy use of the open plan type is 4kWh/m^{2}a higher than the one of the cell type.

From the 100% glazed alternatives only the 4 first cases are presented (see table 7).

Table 7
Energy use for 100% glazed alternatives.

100% GLAZED ALTERNAT.	SPACE HEATING (kWh/m^{2}a)	COOLING (kWh/m^{2}a)	TOTAL (kWh/ m^{2}a)
C-NS45-nor (1)	92	30	177
C-NS45-nor (2)	59	37	152
C-NS45-nor (3)	65	27	148
O-NS45-nor (3)	58	30	152
C-NS45-nor (4)	68	19	143

The impact of different glazing for the 100% glazed alternative is similar with the 60% ones. For example, the (total) energy saving when replacing the triple clear pane (first alternative) of the 60% glazed building with the one of the second alternative is 15kWh/m2a. The same change on the 100% glazed building gives a difference of the total energy demand of 25kWh/m2a.

The impact of plan type is also bigger on the 100% glazed alternative. When comparing the cell and open plan type of the third alternative the difference of the energy use between for the 60% glazed alternatives is 2kWh/m^{2}a, while for the 100% glazed alternative doubles to 4kWh/m^{2}a.

A cross comparison of the 30%, 60% and 100% glazed buildings shows that the energy demand (for heating and cooling) is increased when the glass area is increased. On the contrary, the energy use for lighting (when set points are used) is slightly decreased, without influencing much the overall energy use of the building. The total energy use of the 60% glazed alternative is similar with the 30% one. However, the 100% glazed building (third) alternative uses 20% more energy.

Weighted air temperatures for the working area

There is some variation in the indoor temperature for the normal control (22.7ºC -24.5ºC) and even more for the poor one (21.8ºC -26ºC) (see figure 3). As expected, the open plan type is warmer than the cell type due to the higher internal loads.

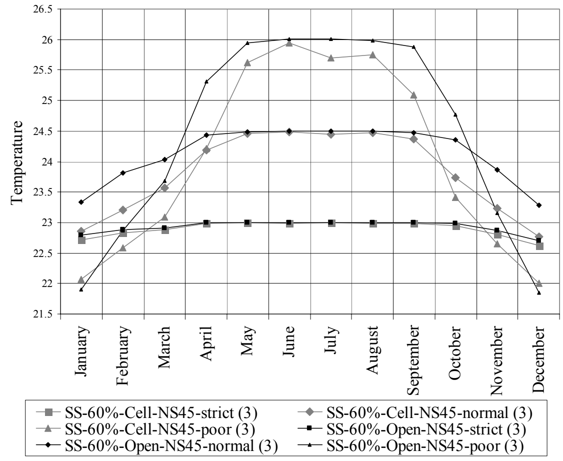

Figure 3. Weighted air temperatures for the 60% glazed building (third alternative).

Weighted average PMV

The PMV variation is similar with the temperature one. The variation is less for the strict control, than for the normal and wider for the poor (see figure 4). However, the most important issue when evaluating the PMV is how close the values are to the x axis. During the summer months the PMV of the strict control set points reaches 0 but on the other hand during the spring and early autumn months the PMV for the normal control set points are better. Since the PMV is an indicator of thermal comfort it is obvious that during the spring and autumn period the occupants, when strict set points are applied, feel cold. The PMV values of the poor control are the lowest during the winter and higher during the summer. Regarding the plan types, the open plan is always warmer than the cell type, as expected. The stricter the control is, the smaller the difference between the two plan types. It is worth mentioning that when the PMV curve is below the x axis the open plan is preferred (and the opposite).

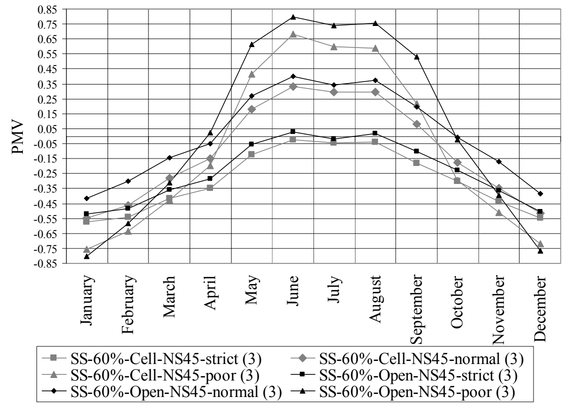

Figure 4. Weighted average PMV for the 60% glazed building (third alternative).

Number of working hours for certain average PPD

For the strict control set point during 93% of the working hours the PPD values are lower than 15% for the cell and 96% for the open plan type. The same values for the normal control set points are 93% and 97% respectively.

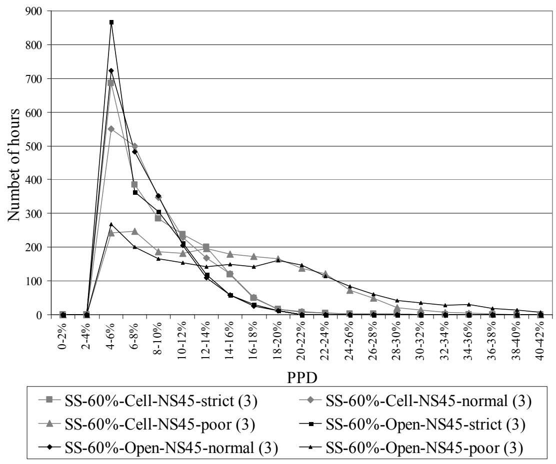

Figure5. Number of working hours for certain average PPD for the 60% glazed building (third alternative). PPD can not be below 5 %, although the results from IDA says so.

The relationship between the PMV and PPD values is very important. Although the PMV values show whether the occupant feels cold or warm, the PPD values gives a more overall view of the perception of thermal comfort (in the PPD calculations the occupancy is also included). Finally the poor control set points result in 57% and 51% of the working hours PPD lower than 15% (cell and open plan) as shown in figure 5, which is usually not acceptable.

Directed operative temperatures

On a zone level the directed operative temperatures were also calculated in order to study the influence of the glazed façade on the perception of thermal comfort. The higher proportion of glass area in the meeting rooms results in a larger variation of the directed operative temperature (see figure 6). The other three zones (corner, single and double office room) differ only in the internal loads. The corner office is the one with lowest loads, thus the temperatures are lower . For cold days the directed operative temperature can be rather low for highly glazed rooms and the opposite for warm days.

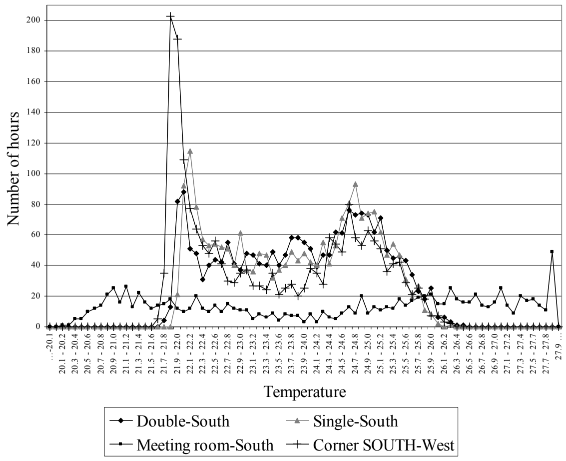

Figure 6. Directed operative temperatures for the 30% glazed building (south orientation).

The number of hours between certain mean air temperatures, PMV, and PPD were also analysed at a zone level, but are however not presented here.

CONCLUSIONS

The use of the dynamic energy simulation tool IDA allows detailed studies of energy use and indoor climate performance of modern office buildings. At a building level conclusions can be made regarding the energy use (for heating, cooling, lighting, etc), the peak loads and the ventilation rates. The zone level gives more detailed output for the mean air and directed operative temperatures, the perception of thermal comfort and the indoor air quality. Combining the results of these two levels allows conclusions concerning the overall building performance.

Detailed energy and indoor climate studies require a lot of attention to the inputs, and are also rather time consuming. Detailed analyses also generate a large amount of output data. For analysis purposes a post processor in MS Excel was therefore developed. Problems encountered were that IDA does not easily or in an accurate way take into account e.g. thermal bridges, air infiltration, window airing, the variation in solar transmittance over a year, daylight and advanced daylight/solar control. Very few dynamic energy simulation programs do this, however. These parameters have to be studied separately and then inputs suitable for IDA have to be created. There is of course the time-consuming possibility to include new calculations modules into IDA, using the advanced level of the program.

The energy efficiency of a building highly depends on the façade construction. Highly glazed buildings should be studied more carefully during the design stage, using a sufficiently advanced simulation tool, since different types of constructions have a large impact on the energy efficiency compared to 30% or even to 60% window area alternatives. The main aim when designing glazed buildings should be to avoid a high cooling demand since this was shown to ensure a low overall energy use. A sensitivity analysis of a glazed building at an early design stage can provide useful information for the energy use and the thermal comfort of the occupants.

The impact of (indoor temperature) control set points on heating and cooling is crucial for the energy use. Narrow heating and cooling set points reduce the effect of thermal mass and increase the energy demand. In terms of thermal comfort, strict controls do not necessarily give the lowest PPD values. One should consider the occupancy density, the clothing, activity level and schedules of the occupants before making a decision as to the allowed temperature interval. The combination of glazing with low solar factor and intermediate or external shading devices can reduce the overheating problems to an acceptable level.

The orientation of a room/building is crucial for the directed operative temperatures mostly for highly glazed facades. The expected position of the occupants (distance from the external wall) has to be considered before choosing the window type in order to avoid discomfort.

The drastic increase of glazing area for highly glazed office buildings doesn't necessarily decrease the use of electricity for lighting. Especially if traditional solar shading with traditional control is used, then the decrease is small.

Office buildings with fully glazed facades are likely to have a higher energy use for heating and cooling, than conventional buildings. For the building studied the increase in total energy use was lowered to 20%, after improving glazing and solar shading. The risk of poor thermal comfort close to the façade is also higher. To add a second façade to these buildings could solve some of the problems with the single skin façade (Poirazis 2004). The analyses will, therefore, be expanded to glazed office building with double skin facades and will also include advanced simulations of daylight. A recently developed double skin façade module for IDA will be used and improved upon. Parallel CFD simulations of double skin facades will be carried out.

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