ADVANCED BUILDING SERVICES SIMULATION SOFTWARE PROVIDING DESIGN SOLUTIONS IN DUBLIN AND BOSTON

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ABSTRACT

The paper uses the latest state of the art dynamic simulation software to analyse and present design information for building design engineers on current design questions in both Dublin and Boston. The design questions analysed include the options for office perimeter HVAC in Boston e.g. VAV with terminal reheat versus VAV with terminal reheat and trench heating. This is explored with full height glazing and 50% glazing to façade ratio. The design information for the Boston design questions are presented in computational fluid dynamics (CFD) format to address the interaction of natural convective air currents and conditioned air from the variable volume terminal units. This information allows thermal comfort analyse to be conducted in the occupied zones for each HVAC configuration. For Dublin the design questions addressed include brise soleil and its impact on the visual conditions within the space i.e. assessing glare. The Radiance daylight computer simulation program is used to provide visual comfort information for the Dublin design questions. Two visual comfort metrics are used i.e. Guth Visual Comfort Probability and the CIE Glare Index.

INTRODUCTION

Occupants in buildings are demanding better comfort conditions. This is putting extra demands on the building design engineer. Many design options are available and to allow the engineer analysis all these options in detail simulation techniques are required.

This paper uses CFD and daylight simulation programs to assess common comfort problems in buildings in Boston and Dublin i.e. cold air movement in full height glazed buildings and glare in passively designed buildings, which make full use of daylight.

COMFORT PROBLEMS IN BOSTON

The simulations were carried out on a 4.5m x 4.5m representative modular office.
Dynamic thermal simulation was used to establish boundary conditions for the model. These boundary conditions were:
Surface temperatures of the external glazing, spandrel panel, walls and ceiling.
Supply temperatures
Supply volumes

A perspective view of the CFD model is shown below.

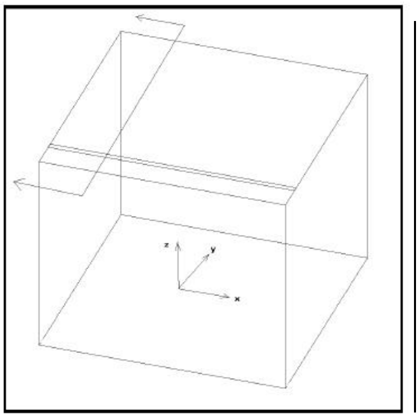


Figure 1: Perspective view of CFD Model

SIMULATION STRATEGY

The model developed was subjected to a number of options, a summary of these being:

Floor to ceiling glazing:
With VAV + terminal reheat only
With VAV + terminal reheat + trench heating

50% glazing & 50% Spandrel Panel
With VAV + terminal reheat only
With VAV + terminal reheat + trench heating

RESULTS
The results obtained can be displayed as follows:
Velocity slice across x-axis
Temperature slice across x-axis
These are shown for each of the four options

COMMENTS
Floor to ceiling glazing, VAV without trench heating – Considerable down draughts exist, the occupied zone is below acceptable conditions as shown in figures 2 and 3.

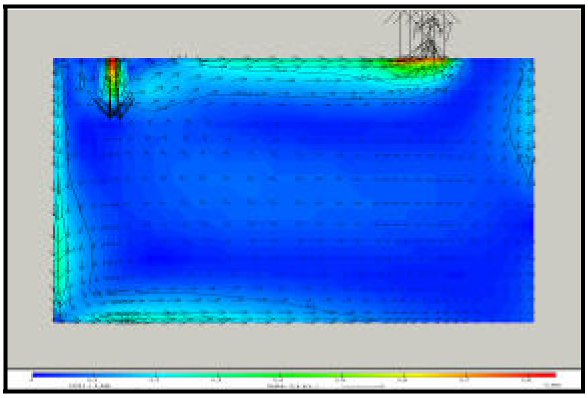


Figure 2: Velocity Slice

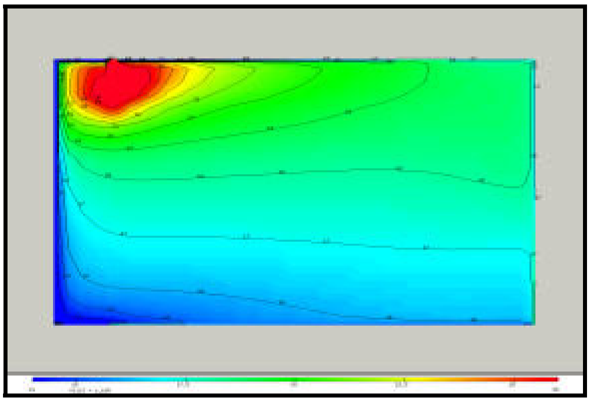


Figure 3: Temperature Slice

Floor to ceiling glazing, VAV with trench heating – The whole of the occupied zone is maintained at acceptable comfort conditions as shown in figures 4 and 5.

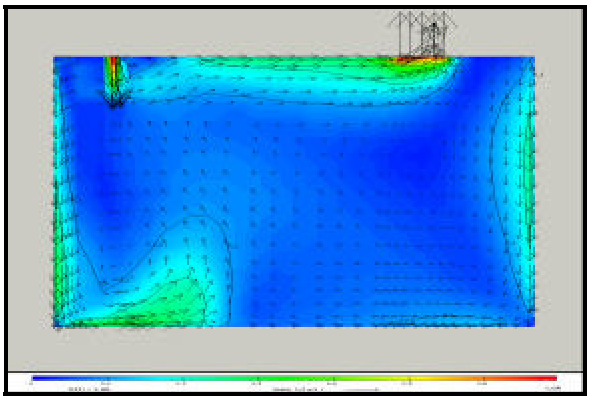


Figure 4: Velocity Slice

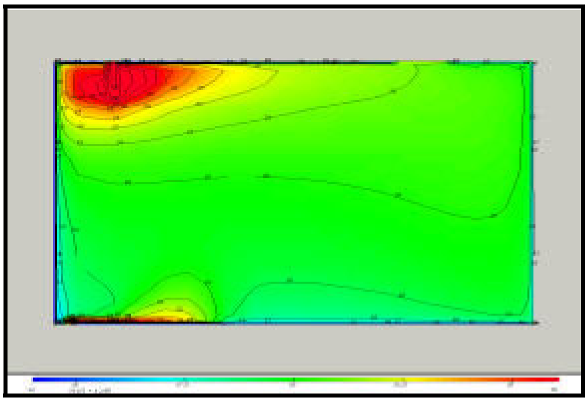


Figure 5: Temperature Slice

50% glazing & spandrel panel and VAV Only – Only a small area of the space which is unoccupied is less than the required room conditions see figures 6 and 7.

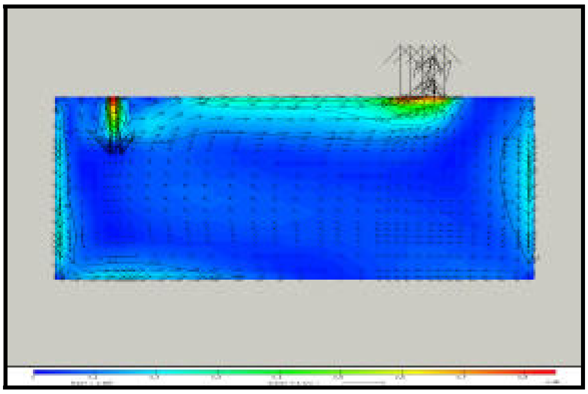


Figure 6: Velocity Slice

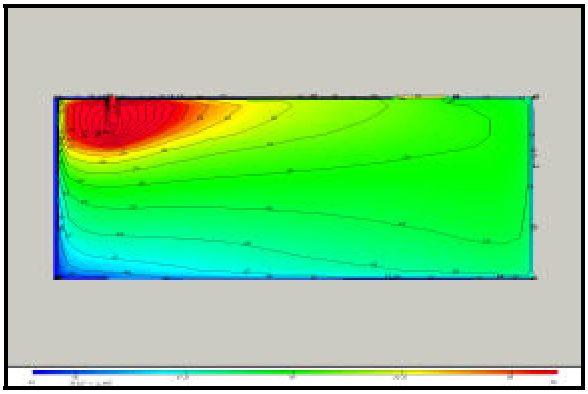


Figure 7: Temperature Slice

50% glazing & spandrel panel, VAV & Trench Heating – The whole of the occupied zone is maintained at acceptable conditions as shown in figures 8 and 9.

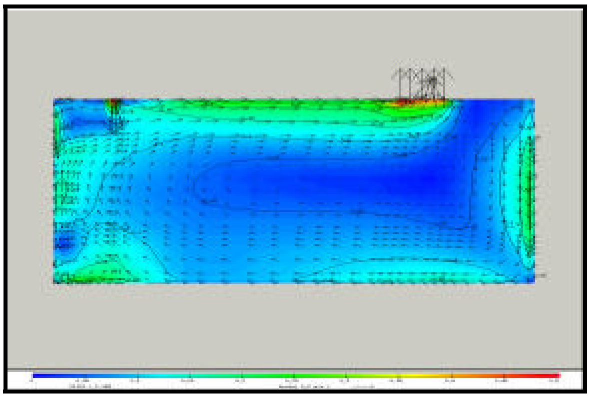


Figure 8: Velocity Slice

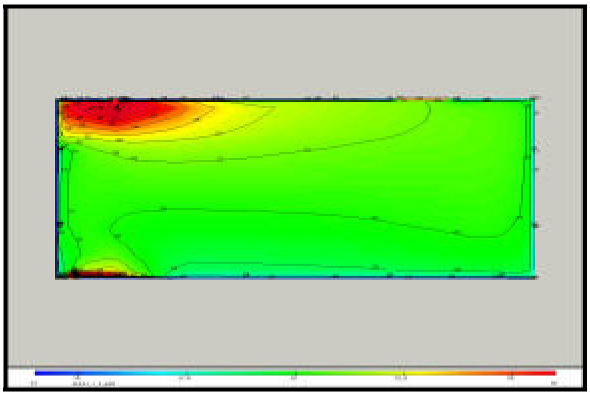


Figure 9: Temperature Slice

DESIGN DECISIONS

On considering the results the following design decisions can be made:
Where floor to ceiling glass exists, trench heating is required to maintain comfortable conditions and prevent down-draughts.
VAV on its own is sufficient to maintain comfortable conditions in the occupied areas when the glazing ratio to spandrel panel is 50:50, this is due to the internal surface of the spandrel panel being at a higher temperature than glass and therefore less down-draughts occur.

COMFORT PROBLEMS IN DUBLIN

Increasingly buildings are being designed in Dublin with passive features to increase the use of daylight and reduce the need for artificial lighting. As glare is a major concern for occupants' simulation is used to ensure that this is avoided. There is also a need to avoid the use of light reflecting glass, which can produce visually unattractive conditions in buildings. The daylight simulation program Radiance was used to investigate both these design issues. The building analysed used brise soleil to ensure a pleasant internal environment.

Background to Lighting Simulation and Glare Analysis

In order to understand the analysis carried out it is necessary to have an appreciation of the fundamental issues behind glare occurrence, its simulation and subsequent analysis.

Causes of Glare

There are two main causes of glare in a building:

Excessive brightness (luminance) within the field of a person's view, this can be caused directly viewing the sun or viewing the sun reflected on a bright surface.

Excessive contrast between light and dark within the building, this can be caused by inadequate distribution of daylight in a space, or the sun's position in relation to the building's geometry.

Types of Glare

The problems associated with glare depend on the extent to which the glare occurs. By definition there are two main types:

Discomfort glare – causes minor discomfort, occupant can usually adapt their view or environment to cope with this, an example would be reflection of a light source on a VDU.

Disability glare – causes major discomfort and can even be dangerous, it is not possible to adapt to this view, an example would be looking directly into the sun.

Simulation of Glare

In order to assess the occurrence of glare in a building, simulation of daylight within the space is required. Radiance is one such means of doing so. Developed at Lawrence Berkeley in California by the Department of Energy it is the most validated and comprehensive ray-tracing program available today.

The methodology employed the following procedure:

It is not practical to simulate all possible dates, times and views. Given the site, location and orientation of the building a number of representative views and times within the building are identified as being potentially problematic.

These 'scenes' are then simulated under a sunny sky in order to represent worst case scenario.

The location and intensity of glare sources are then highlighted on a perspective view of the scene.

These results are then processed through two different visual comfort metrics. This is a first pass in assessing glare occurrence under 'normal circumstances'.

The 'glare thresholds' are then modified to better represent the 'actual circumstances' of the scene.

Reports can be created including observations and comments on the results.

Conclusions can be made by the design team and presented to the client.

RESULTS OBTAINED

The results obtained from the analysis can be considered in three parts, firstly for brightness, secondly for glare threshold and finally for a measure of visual comfort.

Brightness

The scene, locations, sizes and brightness of all surfaces are calculated along with the average background brightness level. The brightness or 'luminance' of an object is measured in Candelas/m^2 (Cd/m^2).

Glare Threshold

Once the brightness of the scene is known the sources of glare can be identified and the resulting visual comfort can be calculated.

In order to do this a 'glare threshold factor' must be set. This is the factor by which the average background brightness must multiplied by in order for an occupant to perceive a glare from an object. For '**normal circumstances**' this factor is 7. For example, if the average background brightness is 300Cd/m^2 any object above 2100Cd/m^2 will be perceived as a source of glare.

This factor has been determined through numerous tests and studies and represents a sedentary occupant in an office type environment.

It should be noted however, that when a uniform brightness is the perceived glare source, the glare threshold should be increased to take account of the eye's ability to adjust to the varying uniform brightness levels. Glare thresholds between 2000 – 3000 cd/m^2 are typical.

Visual Comfort

Once the glare threshold factor is set and the sources of glare are identified they can be displayed on the rendered scene as in Figure 10.

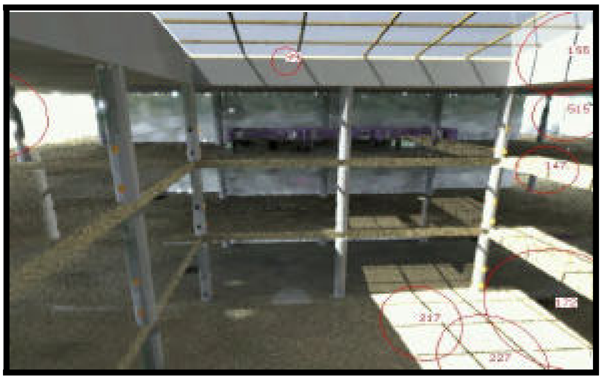


Figure 10:Glare Sources Identified

In order to create a measure of visual comfort these glare sources are then considered in terms of the intensity above the threshold and the size of the source.

Two different visual comfort metrics are used:

The Guth Visual Comfort Probability – This is a measure of the percentage of people who would be satisfied with a particular view.

The CIE Glare Index – A unitless index of visual comfort.

The method of calculation of each of these is different and the CIE Glare Index is used as the international standard. However, Guth is useful in quantifying glare in more understandable terms.

Guidelines on what is deemed an acceptable visual environment are a CIE value of 19 and Guth value of 65% for sedentary conditions and a CIE value of 22 and a Guth value of 52% for Transient Conditions.

*Note that the relationship between the two is not exactly linear and the Guth values in this case have been approximated.

SIMULATED CONDITIONS

Simulated lighting conditions can be generated for any date, time or sky condition (e.g. CIE, Overcast or Sunny Sky) from which a full glare analysis can be carried out.

In order to minimise the number of simulations required and to achieve a feel for the scale of the problem conditions have been selected, which it is thought will give the worst case results. As only glare from the perimeter needs to be accessed, it has been decided to assign the images as follows:

PERIMETER GLARE

Here December the 21^{st} has been selected as our design day. It is thought that this will be the worse case scenario because the sun is lowest in the sky and therefore potentially in the field of view for more of the day.

Glare from windows can arise in several ways. Sunlight may enter and shine directly in the eyes of the occupants, or reflect of visual tasks like PC screens. Only the reflected proportion is of interest to the client. Therefore, to try and quantify the effects two views will be used. They are as follows:

The first view simulated is a typical seating position in the eastern section of the third floor and facing in a western direction. This should allow the designer to quantify the likely reflected glare from the PC screen based on the low angled morning sun. The simulations were carried out for 9.00hr, 10.00hr and 11.00hr.

The second view simulated is to allow the designer to quantify the likely reflected glare from the PC screen based on the low angled evening sun, in the western section of the third floor. The simulations were carried out for 14.00hr 15.00hr and 16.00hr.

All simulations were carried out with a 'sunny sky' to simulate worse case conditions.

ANALYSIS OF RESULTS

Once all of the simulations were complete each scene was initially processed with a glare threshold factor of 7. This highlights the sources of glare and gives the associated comfort metrics for the scene.

A more appropriate glare threshold factor was then applied to the scene, i.e. in cases where a uniform brightness was an issue the glare threshold was increased to 2500 cd/m^2. While in cases where contrast was the issue the calculated glare threshold was considered to be representative of the situation.

Eastern View

Here the daylight penetration was low and uniform; therefore the average Luminance was low, below 100 cd/m^2, resulting in an initial glare threshold of only 560.7 cd/m^2. Thus glare threshold was increased to 2500 cd/m^2 to better represent the situation.

Western View

At 14.00hr the daylight penetration is much greater and the natural lighting is a strong contributor to the contrast glare in the space. From the simulation it can be seen that excessive glare occurs on the computer screen, Thus only the initial glare threshold is required to quantify the glare occurrence.

At 15.00hr glare also occurs in the initial view giving us a CIE value in the range of 25.04. However on consideration of an actual seated position, the glare source would be out of view, thus the glare threshold was increased to 1800 cd/m^2, and the CIE index was reduced to an acceptable level.

At 16.00hr no daylight was available and only artificial lighting was accounted for.

COMMENTS

View 1: East View – Due to the orientation of the building, the sun has moved around to the Southeast side of the building before the occupation begins at 09.00h. Therefore the user position considered (facing Northeast) experiences a CIE index of 19 on the design day.

View 2: West View – Here the user is exposed directly to the low angled winter sun, which causes excessive contrast and thus unfavourable glare conditions on the computer screen i.e. an average CIE index of 25.0 on the work station during the early afternoon hours i.e. 14.00hr. The inclusions of west façade blinds should alleviate this problem.

As the sun moves around the building its influence fades and subsequently improves visual conditions, i.e. a CIE index in the region of 17 –19 occurs on the workstation during the late afternoon i.e. 15.00hr and 16.00hr.

DESIGN DECISIONS

The simulations showed that glare problems were occurring i.e. a glare index in the range 20-25 (CIE) in west sections of the open plan office. However the inclusion of west façade blinds should reduce these glare indices to 11-19 (CIE).

These revised indices are deemed acceptable by international standards.

SIMULATION RESULTS

Table 1 is a summary of the results obtained for the set of simulations conducted. The results provided are an average of the visual comfort across the whole view.

CONCLUSIONS

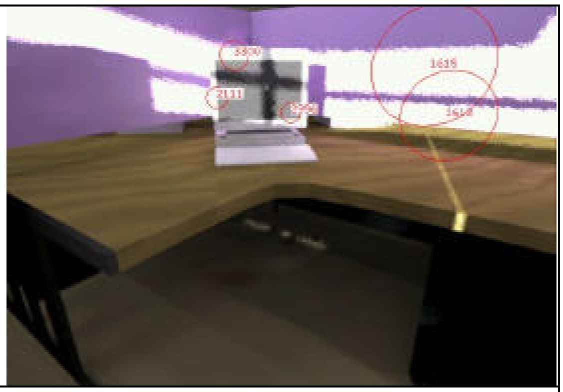
Although computer simulation has been researched, developed and validated to a very high standard building services engineers have not made significant use of this valuable design tool. This paper has shown how the use of simulation can be used to address common design questions that building services engineers are faced with and provide useful information. This type of visual design information is now requested more frequently and the use of the information is allowing design teams to communicate more effectively.

View	Date	Time	Guth (%)		CIE (Index)		Glare Threshold
East (1)	21st Dec	9:00h	55.75	66.41	21.84	19.85	2500
East (1)	21st Dec	10:00h	55.60	66.21	21.97	19.89	2500
West (2)	21st Dec	14:00h	28.35	-	29.05	-	-
West (2)	21st Dec	15:00h	44.17	78.87	25.04	17.50	1800
West (2)	21st Dec	16:00h	56.39	76.01	21.00	19.30	2500

Table 1: Results Summary

'*Initial*' are the results using the standard glare threshold factor (GTF) of 7. The '*revised*' results are those where the GTF was modified increased (those greater than 7).
Typical results are shown below for an East view and a West view.

East View (View No.1)
21st December 10.00hr Sunny Sky



West View (View No.2)
21st December 2.00hr Sunny Sky

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