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USING SIMULATION TO MOVE FROM DAYLIGHTING ISSUES TO FIRST USE OF THE NEW UK CARBON EMISSIONS CALCULATION METHOD

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ABSTRACT

The introduction of simulation into medium-scale building services and engineering firms can provide design teams with access to new information about the performance implications of design decisions. This new information can disrupt "business as usual" and lead to radical changes in how design teams approach projects and in the resulting design.

This paper reports on the experiences of consulting firm Rybka Scotland and the Scottish Energy Systems Group in the redevelopment of a historic structure. The work began as focused assessments on daylighting issues within perimeter atria and adjacent office accommodation. Early access to simulation allowed the design team to identify new opportunities for marketing the project as a "green" building. As the design evolved, further assessments were carried out and this lead to a decision to make use of the new Carbon Emissions Calculation Method (Scottish Part J and English Part L) provisions of the UK Building Code.

In support of this effort, the design team altered their working practices, performance issues were treated explicitly and within the context of integrated assessments rather than isolated component designs.

The paper explores the impact of simulation on the design process from the point of view of the services engineer, the lighting consultant and simulation staff. It discusses the evolution of simulation models, procedures developed during the project, methodologies used to assess the equivalence of novel design elements with code compliant constructions and reviews the methodology used to meet the provisions of the new Carbon Emissions Method. The paper concludes with a discussion of future applications of simulation to the new code provisions.

Keywords: CO_2 emissions, integrated building simulation, use in practice, training.

INTRODUCTION

A motto of the Scottish Energy Systems Group (SESG) is that simulation *does it cheaper quicker and better*. The SESG's general remit is to help professional practices find ways of making this true (McElroy and Clarke 1999). SESG uses the mechanism of "supported technology deployments" to integrate simulation tools and simulation expertise within the design process. Usually such deployments (which involve placing pre-configured computers and experienced simulation staff within a company) focus on one issue and have clear and immediate goals (McElroy et al. 2001). Occasionally, a second deployment is agreed for a more detailed assessment. And sometimes simulation support becomes an integral part of the design process.

This paper reports on the experiences of the Edinburgh offices of Rybka Scotland (a mid-sized consulting engineering practice), the Scottish Energy Systems Group (SESG) who provided initial simulation deployments, and the Energy Systems Research Unit of the University of Strathclyde who carried out detailed thermal and lighting assessments.

The design project involved creating modern office accommodation within an existing "listed" building by inserting a glass box behind the retained historical facade, a portion of which is shown in Figure 1. The scale of the building was substantial (22,400m2), its internal layout complex (see Figure 2) and there was a considerable variation in facade detailing. The proposed office accommodation would be provided on eight levels juxtaposed to a historic facade of six levels. The site presented the design team with considerable variations in exposure to wind and sunlight.

Figure 1: The project.

The design team wished to introduce a number of novel design elements and accentuate the patterns of daylighting perceived from the office accommodation. One aspect of the design was the use of perimeter atria located on several of the facades (see Figure 2), each optimised to deliver daylighting and enhance the adjacent office accommodation with minimal loss of lettable space. These atria were also intended to buffer the office spaces from extreme winter

temperatures, reduce summer solar loads as well as providing a mechanism for passively extracting heat from the offices. The design team anticipated that this would be achieved via the mechanisms shown in Figure 3. Quite how well this idea would work in practice was an issue which would be explored in a number of simulation based exercises.

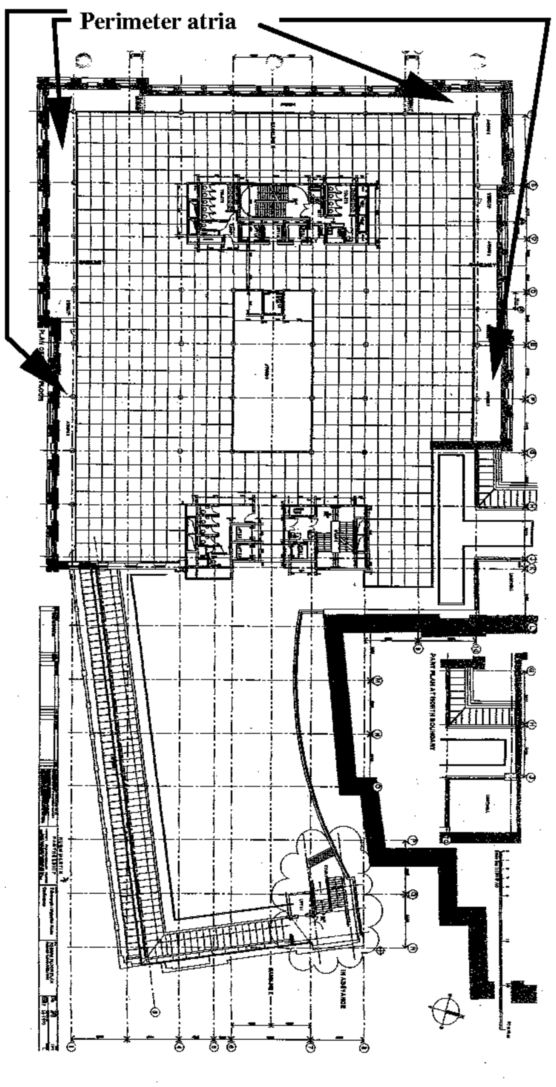

Figure 2: The project plan.

The initial request of the design team to SESG was to assist them in evaluating daylight factors at different points within the perimeter atria as well as the office accommodation. The design team anticipated that daylight would decrease in lower portions of the atria but that daylight from the windows in the facade would partially make up for this. They also wished to know what environmental conditions to expect within the perimeter atria. They hoped that access to data from simulation would help them to optimise the cross section of the perimeter atria to balance daylighting and office floor space.

To support the design team's request, SESG staff selected Radiance (Ward Larson and Shakespeare 1998) as an appropriate lighting assessment tool and ESP-r (ESRU 2003) for thermal assessments. In this project it made sense to develop a hybrid model which would supported both thermal and visualisation issues. The model, shown in Figure 4, is a section through the building which included the massing of the historical facade, structural and framing elements needed to support visualisation. It was zoned to support the requirements for assessing natural ventilation potentials in the atria and raised flooring in the office accommodation. Model creation and attribution was done in ESP-r and exported to Radiance.

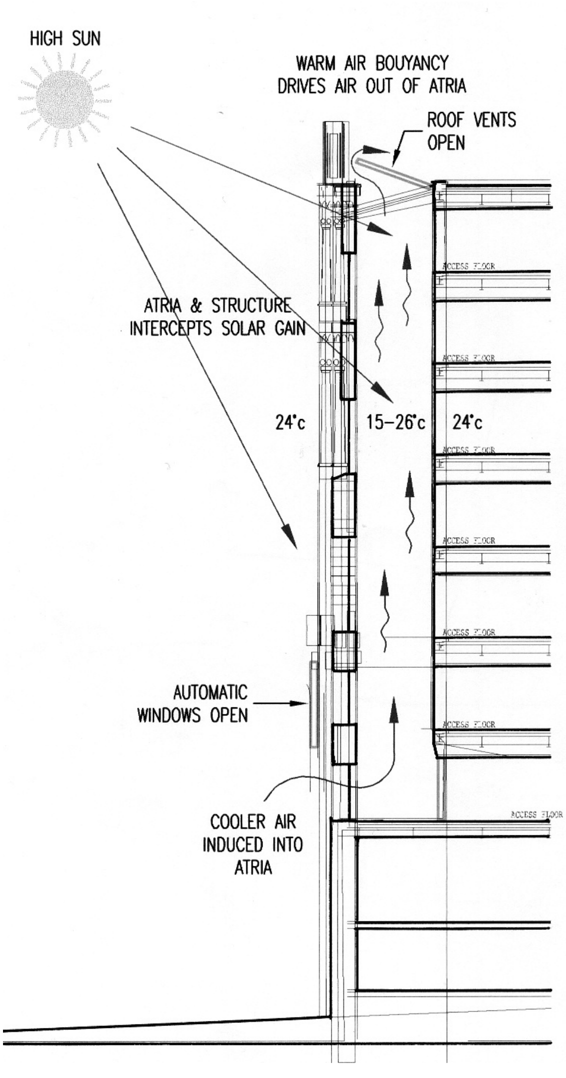

Figure 3: Typical buffer section.

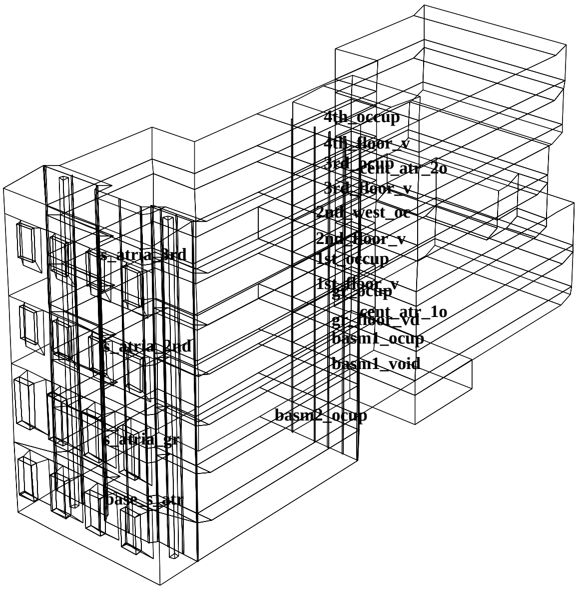

Figure 4: Model of a section of the building.

IMPACT OF NEW INFORMATION

Computationally intensive tools such as Radiance and ESP-r are often used to produce the sorts of engineering performance metrics requested by the design team. Such metrics support standard appraisals, but this paper is about the introduction of nonstandard appraisals into the design process. This began to happen as the simulation team introduced other performance metrics into the discussion - visualisations within and around the project, animations of daylighting patterns and tools to allow the design team to interactively explore their design.

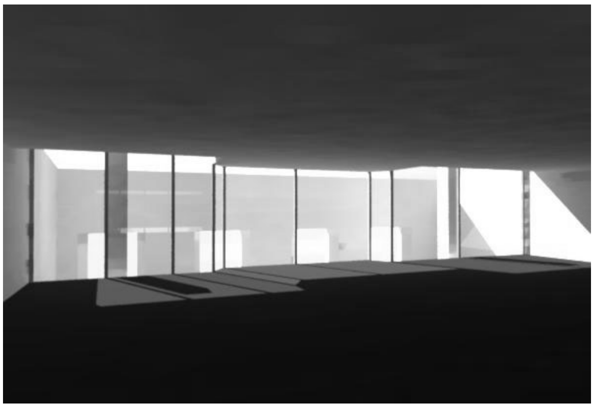

Figure 5: View from office.

This new information, typified by Figures 5 and 6, helped them discover relationships between the existing (historical) fenestration and the proposed internal layout of the office accommodation which were not clearly expressed via daylight factors or noticed n the production drawings. The interactive explorations showed that some of the office accommodation would gain a premium from enhanced views and others would be more difficult to let. Interactive access to lux levels allowed the lighting ngineer to begin formulating design variants. Some "what if" questions were posed and dealt with interactivel and some acted on as follow-up work.

For design teams used to third party/remote simulation support and formal reports, interactive sessions are a considerable departure from "business as usual". In this project, as in many other SESG deployments, the introduction of simulation reduced the time required to investigate the impacts of design decisions. Decisions which had tended to evolve week to week reached consensus between coffee breaks.

SESG speculation is that such changes in the pace of decision making can be attributed to a number of factors. The often pedantic briefing and review process of conventional simulation support and formal reporting tends to be absent from interactive sessions. Design teams will make decisions based on information displayed on a screen or from ad hoc tables captured during a discussion. When confronted by information which is clearly useful and demands immediate attention design teams adopt new ways of working. Design teams are, more often than not, willing to take a short break to allow the simulation process to catch up and are more than forgiving of minor glitches.

Figure 6: View within the buffer space.

Where formal reporting must anticipate which issues are important and tends to compensate by resorting to bulk, an interactive session is often able to adapt its focus to follow the design teams line of inquiry. Thus, interactive sessions tend to be directed searches rather than brute-force parametric explorations. Unpromising options are more easily discarded and the volume of performance metrics which must be dealt with can be reduced. In the case of differing interpretations, clarifications tend to be addressed as they are noted. And where issues cannot be resolved interactively, the follow up process is often much more efficient.

From the point of view of the simulation team, interactive sessions offer opportunities to clarify the thermophysical nature of the design, identify the design teams expectations and the issues that need to be addressed via simulation. Such clarity allows concise models to be produced, gives clues about which performance metrics to be supported and which issues might need to addressed in future models. Such information can constrain the resources required to deliver simulation work and enhance deliverables.

To balance this, interactive sessions require careful preparation. They demand considerable knowledge of the tools being used as well as how to constrain the level of detail in a model and assessment parameters for rapidity of feedback. Interactive sessions demand a balance of attention between the needs of the design team and the needs of the assessment tools. Few simulationists are geared to this mode of operation or are comfortable with the associated risks. However, SESG experience is that simulationists can acquire many of these skills.

From the standpoint of the building services engineer and lighting designer in this project, the initial daylight simulations provided valuable information relating to both the open plan office space and atria buffer zone. The analysis of the atria indicated that the buffer space would have a good quality of daylight. This enabled the lighting designer to provide an integrated solution utilizing light fittings that would be complimentary to the space.

If this had been the end of SESG participation in this project, it would have been considered a successful deployment of technology. Indeed, Rybka found the process instructive and decided to evolve their practice to support in-house assessments.

EQUIVALENT CONSTRUCTIONS

Based on the initial visual assessment, the design team evolved the design of the perimeter atrium and then requested a second technology deployment to be focused on thermal and ventilation assessments. This proved a useful mechanism for training Rybka staff in several aspects of the production of thermal and air flow models. Simulation staff then completed the models and undertook a number of thermal assessments to clarify how these spaces might act a buffers to winter heat losses and to moderate summer solar loads. It was at this point that the extent to which the buffer space might draw heat from the office accommodation during the cooling cycle was identified.

From the point of view of the building services engineer the initial thermal assessments gave an early indication of the requirements for background heating within the atria. The dynamic analysis showed which combinations of occupancy and weather would result in condensation risks in a space which planning constraints would not allow modern fenestration systems to be used. This allowed the services designers to incorporate background heating systems and to deal with the minimal loads imposed, at an early stage in the development and to more accurately determine specific system requirements and spatial requirements as the design evolved.

From the point of view of the building services engineer the early notice of the potential reduction in overall heating requirements and cooling energy consumption allowed selection of a chilled beam system. Consideration was then given to how the buffer space could be used for night purging and early stage design process was revised to enhance the benefits of the perimeter atria in this regard.

It was clear that the building was substantially driven by internal loads and that additional mechanisms for rejecting heat from the building would be helpful. The simulation team argued for using single glazing in the internal facade so that excess heat could be more easily pass to the perimeter atria. This concept conflicted with the provisions of the building code which restricted building facades to particular heat loss characteristics.

The question was how to evaluate the performance of a perimeter atria in such a way as to demonstrate that it is equivalent to conventional code compliant wall constructions. To answer the question of *what is the equivalent U value of a not particularly well sealed 1m thick historic facade with 1.5m buffer space and a glazed inner facade* the simulation team decided to use the thermophysical equivalent of "if it walks like a duck...".

The first test was to evaluate whether, under the static outside and inside conditions, a section of the proposed building facade would exhibit the same pattern of inside surface temperatures, radiation and convection as a code compliant facade. The second test was that the proposed and standard facades would exhibit the same pattern of heating and cooling demands.

A model which included a 12 metre section of perimeter atria and office accommodation as proposed and a section of office accommodation strictly conforming to the code was created. Detailed assessments, suported by performance graphs such as the surface convection plots shown in Figure 7, confirmed the equivalence of the proposed and code compliant design for the above two tests. In the graph, static ambient temperatures and overcast conditions occurred from hours 22 to 32 and 36 to 40 and during these hours the predicted surface convection was substantially the same.

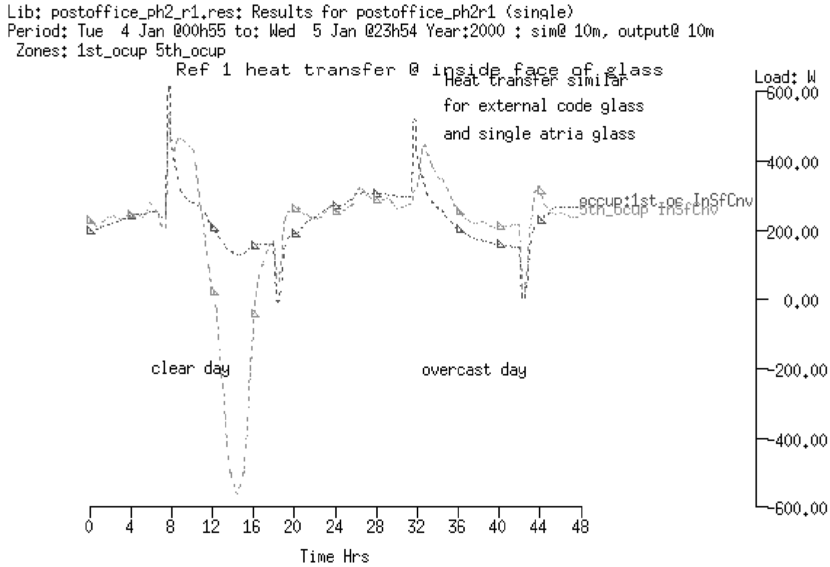

Figure 7: Plots of surface heat transfer.

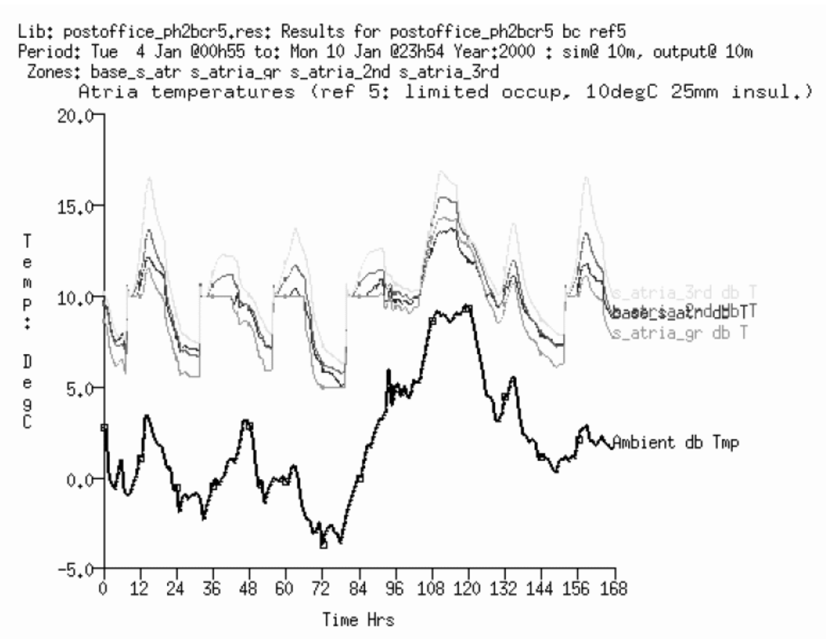

Figure 8: Buffer performance.

However, it required quite a bit of time and re-expression of the results to convince the design team that their initial idea offered such benefits. Essentially, practitioners forget that they used to do building physics and simulationists forget that no one else in the room gets excited about heat transfer coefficients, and the actual patterns of heat transfer across the buffer space were obscured in the sea of numbers.

The buffer's primary action, was to reduce the temperature difference which the inner facade had to compensate for and isolate the inner facade from the wind. Figure 8 shows the includes the temperatures at various points within the buffer space and the outside ambient temperature. Being unoccupied, the buffer only required frost protection and solar gains limited the demand for background heating.

Thus the temperature difference dropped from ~20°C to ~8°C and the convective heat transfer normally associate with an outside exposure was replaced by one associated with an internal wall. In the event, background heating for frost protection was limited, even with minimal upgrading to the historic facade and fenestration.

In projects such as this, conventional approaches to code compliance, which focus on heating requirements, are increasingly counterproductive. Buildings substantially driven by high internal loads and which attempt to adhere to the old code provisions inevitably require substantially more cooling and generate greater quantities of CO_2 emissions. The option for design teams to balance overall energy demands and emissions offers substantial scope for better designs as well as contributing to governmental targets.

CARBON EMISSIONS METHOD

Essentially the UK Carbon Emissions Method allows design teams to shift the assessment focus from winter-only heating performance to a balanced overall performance which can take into account all environmental systems. This project is one of the first to make use of these new provisions in Scotland. Setting precedents is not a comfortable process and practitioners and their clients do not lightly take risks unless the benefits are substantial.

The design team wished to demonstrate both that the project was environmentally sound and that capital diverted from conventional systems would provide an improved rate-of-return and higher occupancy rates if invested in the facade. The case for doing this was thought to be much clearer under the new provisions of the building code, but the design team was not sure that sufficient CO_2 reductions could be found to gain approval.

It was realized that the standards of proof required within the project as well as in communications with the client and the planning and building control authorities would require adaptations to working practices. The anticipated capital and operational benefits had to be proved from first principles, the various facets of the design had to be seen to work together under realistic usage scenarios and the underlying assumptions needed to stand up to close scrutiny. This also required simulation staff to provide additional views into the performance data to clarify the benefits.

The simulation team proposed that the necessary proof could be delivered by assessing typical portions of the proposed and nominal building and then scaling the results to the whole of the building. This recommendation was made because the significant resource for QA which would be required to explicitly represent the building. It was further suggested that the model also include diversity of use. Figure 9 shows the thermal model which was composed for the proposed building. Each primary facade type and level/type of occupancy were represented in the model.

Figure 10 shows sections of the nominal building which replaced the novel design elements with conventional facade treatments. Again, diversity of use was included in the nominal building.

Simulations indicated that some portions of the proposed design would significantly reduce CO_2 emissions and other portions of the proposed design performed less well than the nominal building. When scaled to the whole building the proposed design was an improvement on the nominal design.

This raised a number of questions in the design team regarding changes to the proposed design which would result in lower emissions and the costs and benefits of improving performance in specific sections of the building to compensate for deficiencies in other areas.

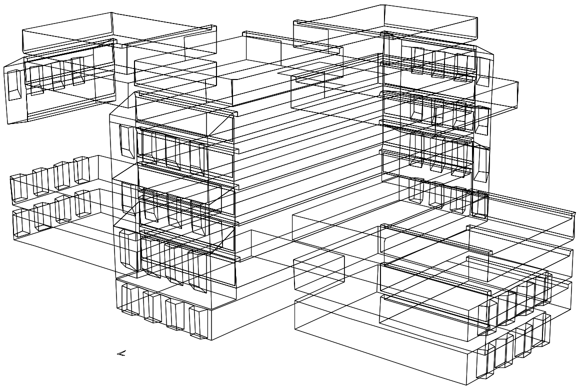

Figure 9: CO_2 emissions proposed model.

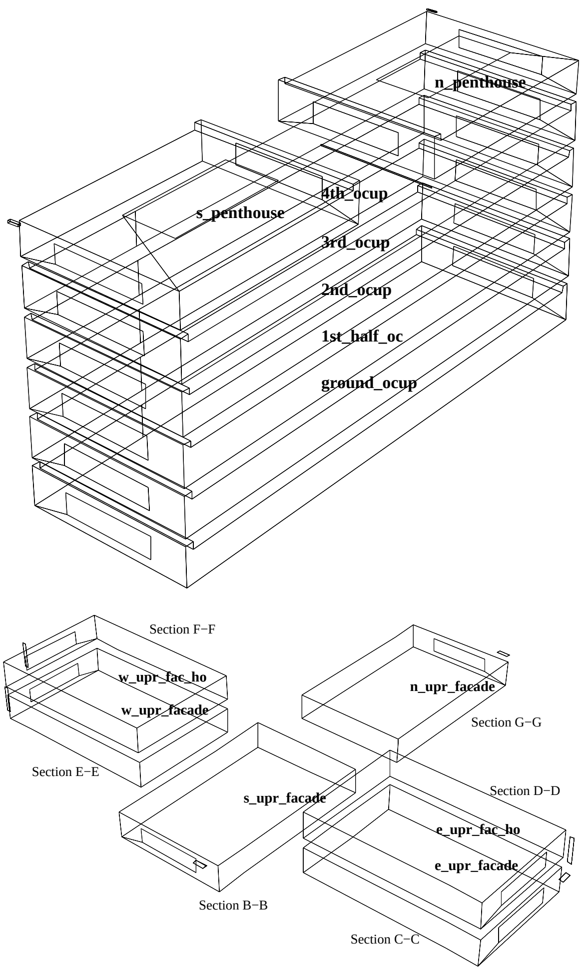

Figure 10: CO_2 emissions nominal model.

- A balanced natural ventilation strategy within the buffer spaces was found to be critical. Benefits within the spring, autumn and winter months would be lost without a good strategy for purging atria air in the summer. Temperatures at the top of the stack would otherwise be far higher than the external ambient and impose an additional cooling load on the occupied space.

- The requirement for lower insulation levels in some areas of the building meant that money was available to add additional measures such as solar control glazing to the highly glazed penthouses. This in turn added additional benefit to the project reducing peak and annual cooling demands within the high quality penthouse spaces. The Carbon Emissions Method allowed for such trade-offs.
- Many of the no-cost enhancements discovered during the design process related to periods which are mostly ignored by design teams - in particular the transition periods where equipment is running at part load.
- The simulations identified that there was a significant cooling resource available by controlling the timing and rate of natural ventilation within the perimeter atria. When this was invoked outside of nominal office hours it acted as a low cost night purge. It was also shown that reduced flow rate mechanical venting overnight could be used to modify the timing of cooling demands.
- In some cases, value engineering options which simulation identified, could not be implemented because of other design constraints. For instance, most of the time, cooling loads (and thus CO_2 emissions would have been less) would be reduced with single glazing between the offices and buffer space. This would have yielded considerable cost savings, but was rejected because of poor acoustics.

According to the building services engineer, the carbon emission study not only showed compliance with the Building Regulations and improved the BREEAM assessment rating (useful for marketing purposes), it provided valuable insight in to the dynamic performance of the building and perimeter atria zones which contributed to value-engineering tasks. For instance, the option to increase the u-values of the retained existing facades, from the level set out within the current regulations, to a level where the building was achieving maximum benefit in terms of the heating and cooling energy demands. This freed up resources to add solar control glazing to the penthouse level. This in turn added additional benefit to the project reducing peak and annual cooling demands within the high quality penthouse spaces.

SIMULATION AND CO_2 METHODS

Many of the challenges in this project related to the wording of the code, the nature of the burden of proof required and the tools and methods employed. The Carbon Emissions Method requires that the proposed design be compared with an equivalent (nominal) building which conforms to the code. Rather than specifying the specific burden of proof, the code makes reference to the CIBSE Applications Manual AM11 (CIBSE 1998). AM11 sets out a criteria for how building thermal assessments tools should be employed in best practice and provides lists of data sources and good practice guides. However, the AM11 was written prior to the code and was intended as a reference for best practice use of simulation tools.

This provided a rich source of debate. For example, AM11 discusses the concept of comparative studies using proposed and nominal designs, but there is some scope for interpretation for applying its methods for code compliance. Clearly, small power demands and lighting will contribute to CO2 emissions. For some projects code approval might be based on an alternative lighting control regime but the mechanism of proof is not strictly defined as it is in other building codes.

It was the consensus within the design team that it was reasonable that the proposed and nominal designs would include diversity of tenancy as well as some diversity of occupancy and small power demands. This informed the client that the building would function well when the building was not fully let and if anticipated occupancy types were not realized. It would, however, have been helpful if the code included further guidance on such issues.

Clearly, it is in the interest of simulation tool vendors to reduce the tedium of creating nominal design models. Given the degree of interpretation which this project was confronted with, it is not altogether clear what the **rules** for generating nominal models might be. Without access to, and an ability to modify such rules, complex projects such as this one might be less clear in their proof and the design team less well informed.

For example, in this project, a substantial portion of the project was below ground level. Not only is there no equivalent in the older provisions of the code, AM11 does not set out specific methods for assessing below ground constructions. It was not particularly clear whether the nominal design should include the same area of below ground exposure or should revert to the convention that only exposed facade elements need to be included.

The Carbon Emissions Method rewards designs which show a balance between heating, cooling, small power and lighting loads throughout the year. Although this implies that integrated simulation approaches might be better at verifying that this balance has been obtained, AM11 presents integrated simulation approaches as but one option among many. Again the design team is left to propose what mechanism to use to prove their case with minimal guidance from the code.

CONCLUSIONS

A joint project of SESG and Rybka Scotland has highlighted how new information delivered to the design process assisted in the deployment of novel designs ideas. The timing of the information was of particular value to the mechanical services engineer as it supported better planning of the systems and flexibility in system types.

It has also shown that SESG supported technology deployments can alter the pace of decision making, allow more design alternatives to be assessed. From Rybka's point of view, both the frequency of interaction between the design teams and the simulation team and the multiplicity of viewpoints which contributed to the evolution of the design. The

project highlighted the benefit to be obtained from adopting an integrated and holistic approach to building energy assessment.

It is not yet clear the extent to which the holistic approach altered the cost of design. On the one hand, the analysis had beneficial impact on the services installations and the architectural and structural elements of the building. The ability to dynamically analyse the building performance over the highly variable seasons in Scotland enabled the design team to add value to the project without compromising budgets.

On the other hand, each of the participants in the design process adapted their work practices to support the much higher standard of proof required to implement the final design proposal. Fees for simulation work and the time required to understand and act on the predictions had to be factored into the project costs. Quality control procedures for Rybka and within the simulation tools evolved during the project.

In terms of the Carbon Emissions Method, it has been demonstrated that there are considerable benefits in the design process to using the new provision of the code and that simulation can be used to support the requirements of the Method. It has also highlighted some of the misunderstandings which emerge as new performance metrics are included in the design process.

The project exposed several problems in existing QA procedures within ESP-r and Radiance based projects. It also proved somewhat tedious to scale predictions from typical sections to whole building performance. These issues are now being addressed and should allow future large scale projects to proceed with greater efficiency.

REFERENCES

McElroy L B, Clarke J A. 1999. "Embedding Simulation Within Energy Sector Businesses", Prod. Building Simuation '99, Sixth International IBPSA Conference, Kyoto, Japan. pp263-268.

McElroy L B, Clarke J A, Hand J W, Macdonald I A. 2001. "Delivering Simulation to the Professions: The Next Stage", Prod. Building Simulation '01, Seventh International IBPSA Conference, Rio de Janeiro, Brazil. pp831-836.

Ward Larson G, Shakespeare, R. 1998. *Rendering with Radiance, The Art and Science of Lighting Visualization*, Morgan Kaufmann, San Francisco, California.

ESRU 2003. http://www.esru.strath.ac.uk

CIBSE 1998 *Applications Manual AM11: Building energy and environmental modelling* ISBN 0 900953-85-3