HOLISTIC APPROACH

Whole building design that includes structure, materials, façade and internal organisation, can provide a tool for delivering low-carbon performance

MASTERCLASS
Professor Doug King

This month's article – the last for this current series – looks at the engineering of whole buildings to achieve low carbon performance

This Masterclass series has ranged widely over passive and active environmental design issues, human comfort and even the philosophy of engineering. This demonstrates the breadth of the profession – encompassing mechanical and electrical systems design, public health engineering, façade engineering, lighting design and, increasingly, building physics and carbon performance.

At times it can be difficult to coordinate the efforts of architects, structural engineers and building services engineers to achieve project goals. We must ensure that the industry does not become so fragmented that we cannot act coherently to achieve the imperative of low carbon performance for buildings.

Given the existing disparities in the construction industry, in order to do anything meaningful in terms of moving to a low carbon society, we need a consistent framework within which we can apply knowledge embodied in a design team. In some parts of the world, building services engineers are referred to as systems engineers. I would say that this is apt, as the principles of systems engineering are inherent in much of what we do as building services engineers.

The systems engineering approach recognises that complex products such as buildings, aircraft or vehicles require

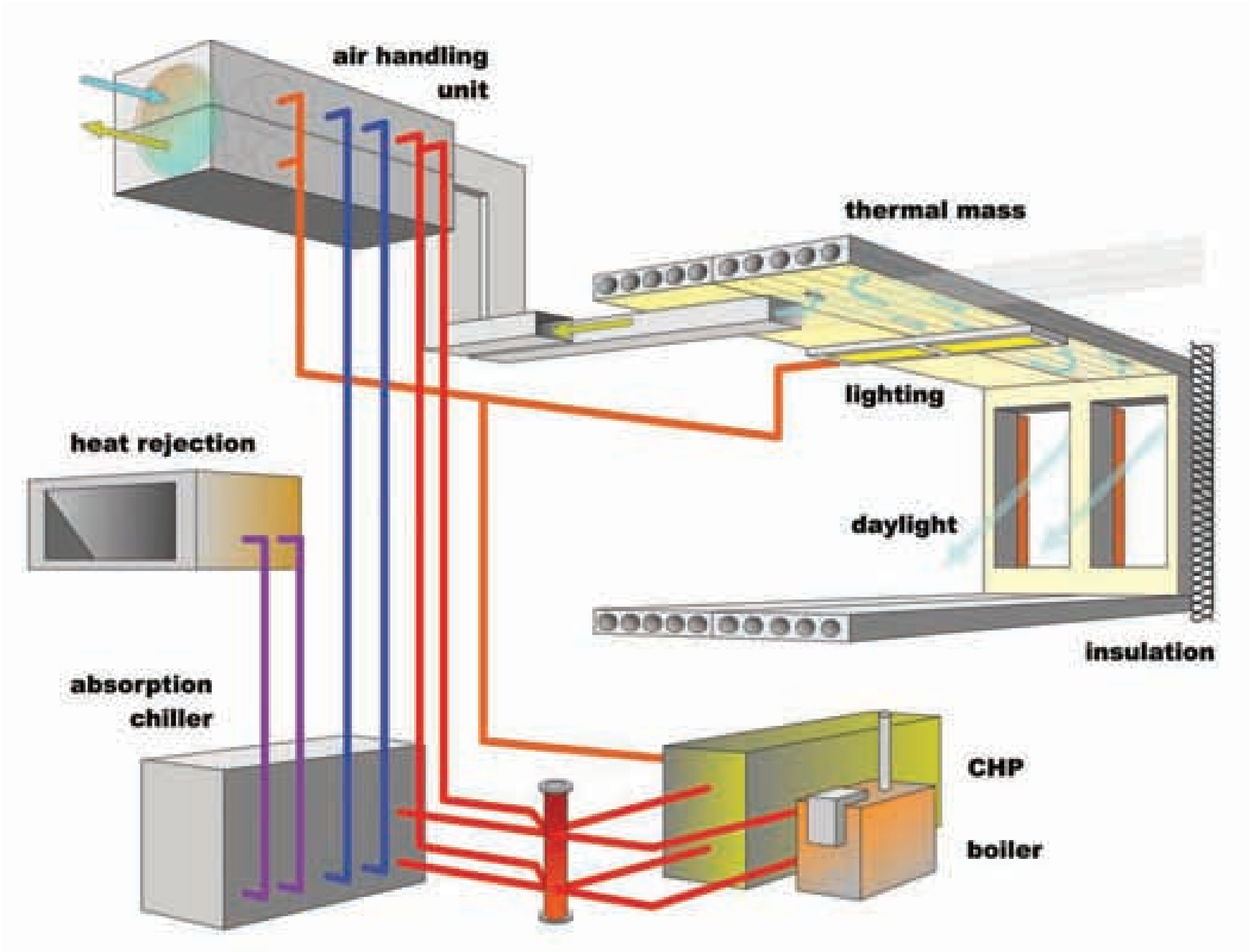

Figure 1: The comfort system for a building is likely to comprise elements of building fabric in addition to traditional heating, ventilation, air conditioning and lighting installations. Once low and zero carbon technologies are added – often with specific operating parameters – the total system can become vastly complex. In order to achieve the optimum performance for the building while ensuring the sub-systems and components all function in harmony, a rigorous approach to specification and verification of performance requirements at all levels of system integration are needed

the contributions of many engineering disciplines to work in harmony. Systems engineering as a discipline sets out a methodology for ensuring that the many disparate component sub-systems are developed to deliver optimum performance in their own right while still contributing to the overarching performance goals for the completed product.

I believe that we need to look to the discipline of systems engineering for guidance on how building services engineers can take the lead role in delivering low carbon construction projects.

In our working lives we are already familiar with the issues of interoperability between particular parts of the building services installation. For example, when designing a heating installation using a heat pump in place of a conventional boiler, we already understand the internal operation of the heat pump system and how this potentially interacts with the external heating distribution system. If we fail to match an appropriate form of heat utilisation to the limited temperature range of the heat pump, then it will fail to perform and so the entire heating system fails.

Systems engineering simply formalises the process by which we already make decisions about building services installations. The methodology suggests breaking down the design of a complex system, such as a building, into a range of manageable sub-system designs. Each of these sub-systems can then be designed for optimum performance. However, we should undertake the sub-system specification and design, not as an isolated project, but taking into account the interaction between sub-systems and their overall contribution to the final carbon performance of the building project.

Key to the systems engineering approach

is the specification of performance targets at each level of integration. Thus, at the highest level, the completed building, we will set targets for the carbon footprint in kgCo2/SQ m, or a similar suitable metric based on occupancy and use. At the lowest level of systems integration we would aim to choose components, such as pump and fan motors, which deliver the maximum energy efficiency. Sometimes these targets are set for us: the Building Regulations stipulate the minimum allowable luminous efficacy for light sources, for example.

At intermediate levels of integration we would set targets, aligned with the overall performance objective, for the output of completed sub-systems. For example, legislation now dictates the maximum specific fan power for a ventilation system or the minimum coefficient of performance for chillers. However, in order to ensure that our overall performance goals are met, we should be setting appropriately aligned performance requirements for all the sub-systems and assemblies.

As the components and sub-systems are assembled to complete the product, the systems engineering methodology calls for testing at each increasing level of integration, referring back to the original component and sub-system specifications. Once again, building services engineers are completely familiar with this process. Components will undergo testing in manufacture as will sub-system assemblies such as air handling units. Sections of the system assembled on site, such as pipe and duct distribution, are all tested to ensure that they comply with the specified performance.

Once the systems are assembled, the building services specification calls for commissioning. During commissioning the systems are operated, tuned and their overall performance is tested. The introduction of mandatory air pressure testing in the building regulations now means that the building fabric is also included in the commissioning process, although not always integrated with commissioning of the mechanical and electrical systems.

However, it is still rare that we specify whole building commissioning or operational testing, an essential step in the systems engineering method, and one that is necessary to complete the integration of the building services systems with the fabric and the building operation. When the occupant of a new building is uncomfortably cold and cannot rectify this by turning the heating up any further, then it is likely that the building services engineer will get a call, even if the failing turns out to be one of insulation or draught proofing. It is time, therefore, that the building services profession also took control of the building fabric and operational commissioning, in order to avoid these issues.

The final step in the systems engineering methodology is monitoring, feedback and continuous improvement. This step allows the user of the completed product to refine and optimise its operation for better performance over time. This step also allows the original design decisions to be validated against the final building performance, thus allowing learning from the project to be transferred to the next project to incrementally improve performance. The building services profession has, for many years, been calling for post-occupancy evaluation of buildings and publication of the data in order to permit this cycle of continuous improvement.

Building services engineers are already experienced in many aspects of systems engineering, even if they are not always able to see this approach through to fruition. If we could expand such a systematic engineering approach to encompass the whole building design, including the structure, materials, façade design and internal organisation, then we would have a very powerful tool for designing and delivering replicable and continuously-improving low-carbon performance.

When clients and other design team members are increasingly looking to the building services profession to deliver carbon savings as well as comfort, it becomes essential that we equip ourselves with the tools to manage the contributions of others, as well as the many disparate systems that we are responsible for designing. **CJ**

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