ENERGY EFFICIENCY PRACTICE IN OFFICE BUILDING

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Summary

The conflicting demands of growing building energy use against targets for reducing carbon emissions coming from the building sector has gained widespread attention. Energy efficiency is one of the few techniques which has been used to tackle the great concern of increased energy use and carbon emissions in many countries. Energy efficiency is considered a key element of energy conservation and a contributor to the reduction of carbon emission in many countries throughout the world, not least because of the high proportion of the total energy used by the buildings the building sector. Some countries have now introduced building regulations concerning energy conservation and the use of energy efficiency measures.

In the UK, the government has introduced the Building Regulations Approved Document Part L regarding the conservation of fuel and power. This paper presents a showcase of a newly built office buildings in the UK and demonstartes how the energy efficiency technology in buildings might contribute towards energy conservation and fully comply with the building regulations. A large array of energy efficiency solutions are used such as a ventilation system with an efficient high heat recovery system, lighting controls linked to daylighting, etc. Using energy efficiency technology the office building in case study has shown compliance with the building regulations and has also conserved energy. This paper will demonstrate that energy conservation and compliance with building regulations are achieved through early incorporation into the building design.

The show case of an office building in this paper brings practical applications to building services engineers and consulting engineers who might want to design an office building that conserves the energy. Certainly, Part L of the Building Regulations has statutory standing as legislation in the UK, however this regulation has been amended and synchronised with the Directive on the Energy Performance of Buildings (EPBD) set up by the European Parliament and Council on energy efficiency of buildings. So this study will not be only useful for building engineers in the UK but also in the EU as well as any part of the globe which use EPBD as the basis to develop local energy codes.

Keywords: Sustainable Building, Office Building, Energy Conservation, Building Services, Building Regulation

1 Background

Buildings are responsible for at least 40% of energy use in most countries. In the EU region for instance, 40-45% of the total energy used is consumed by buildings [2, 5, 7, 8]. This striking figure is mainly the result of using mechanical and electrical equipment as part of M&E systems in building for heating, ventilation, air-conditioning and lighting. Energy consumption is growing as construction booms, especially in countries such as China and India. The growing demand of building energy use has brought concerns about rising energy use to such a level that stern measures have been taken in many countries thought the introduction of building regulations concerning energy conservation.

Energy efficiency in the building sector has been introduced through these building regulations as it is considered a key element of energy conservation and contributes towards a reduction of global carbon emissions.

It has been estimated that energy efficiency technology has the potential to reduce carbon emissions by 60% or more, which translates to a billion tonnes of carbon and conserve conventional energy in the process [4, 5].

In lighting for instance, various energy efficient lighting technologies have been used to save energy and cost in many types of building [17, 18].

Given that building regulations exist that promote energy conservation through energy efficient technology, energy efficiency provides a potentially important vehicle for taking opportunities to improve energy and CO_2 performance.

In the UK, the government has introduced a range of legislation to achieve energy conscious buildings, promote energy conservation and sustainability in the built environment. The Building Regulations Approved Document Part L, the Conservation of Fuel and Power has been in force since 6th April 2006. The intention is to reduce the substantial contribution of the built environment to energy consumption and carbon dioxide emissions.

This paper analyses the case of a newly built office building in England against existing regulatory provision and discusses ways in which it could show how the technology in energy efficiency in the building might contribute to energy conservation. Furthermore this paper will demonstrate and review how an office building can be designed to utilise energy efficiently and therefore conserve the energy and also remain in full compliance with Part L of the Building Regulation.

2 Aims

The aim of this paper is to present a case study of a newly built office building in England and demonstrate how technology in energy efficiency contained in the building might contribute to the energy conservation and therefore achieve full compliance with Part L building regulation. Furthermore this paper aims to review how an office building can be designed to utilise energy efficiently and therefore conserve the energy from the outset.

3 Methodology

A case study which demonstrates the main features of energy efficiency techniques is presented. The case is then analysed and evaluated against the intended compliance with Part L of the Building Regulation.

Various data sources were used for the analysis, including:-

- The project concept design document and reports
- The project tender documentation.
- Data from the utility company, & utility statistics from the UK
- Data from trusted sites / organizations (e.g. CIBSE, BRE, BSRIA)

The building in the case is taken directly from one of the authors own projects when he was working as a lead building services engineer. The grounds for the selection and analysis in this case is based on the fact that there were some good practices utilised that could be adopted to improve the building energy performance and energy conservation in other office buildings.

4 Energy Efficiency, Conservation and Building Regulation Part L

The terms 'energy efficiency' and 'energy conservation' have often been used interchangeably in various contexts and discussions, but they do have very different meanings. Energy conservation is reduced energy consumption through lower use of energy services, e.g. lower heating levels, through turning down thermostat levels or capacity/consumption limits on appliances which are often set by standards. Often energy conservation means doing without to save money or energy. It is strongly influenced by regulation, consumer behaviour and lifestyle changes.

Energy efficiency is the ratio of energy services out to energy input. It means getting the most out of every unit of energy you buy. It is mainly a technical (and historic) process caused by replacing the old equipment which is less energy efficicent for newer more efficient ones. It is generally a by-product of other social goals: productivity, comfort, monetary savings or fuel competition.

Building Regulations in the UK (with the exception of Scotland who have their own) are regulations that seeks to ensure that the policies set out in the relevant legislation are carried out. Therefore, building regulations approval is required for most building works in the UK including refurbishment in certain circumstances. Building Regulations Approved Document Part L imposes the requirement on building work to ensure that a reasonable provision is made for the conservation of fuel and power in buildings. It is part of the UK government strategy to reduce greenhouse gas emissions and to address global warming. It splits into four documents:

- L1A New dwellings
- L1B Existing Dwellings
- L2A New Buildings other than Dwellings
- L2B Existing Buildings other than dwellings

5 Brief description of the project in the case study

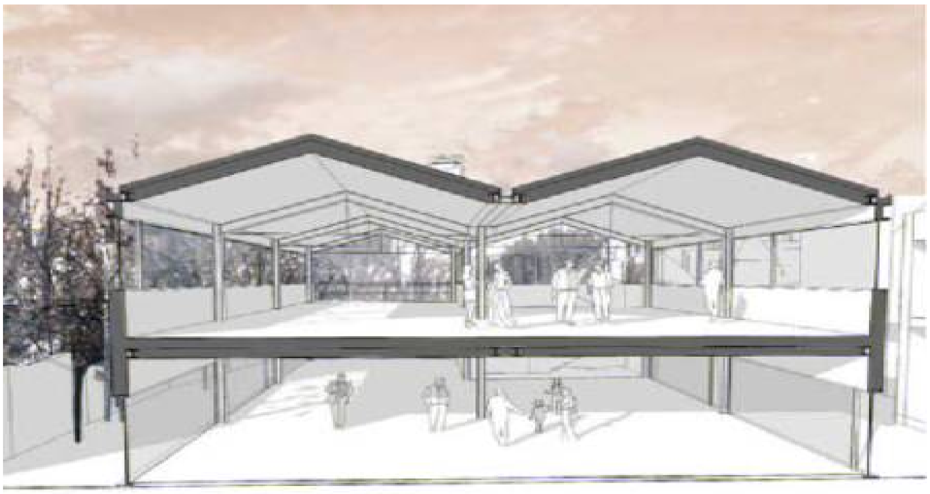

Fig. 1 The Building Project in the Case Study – A Two Storey Office

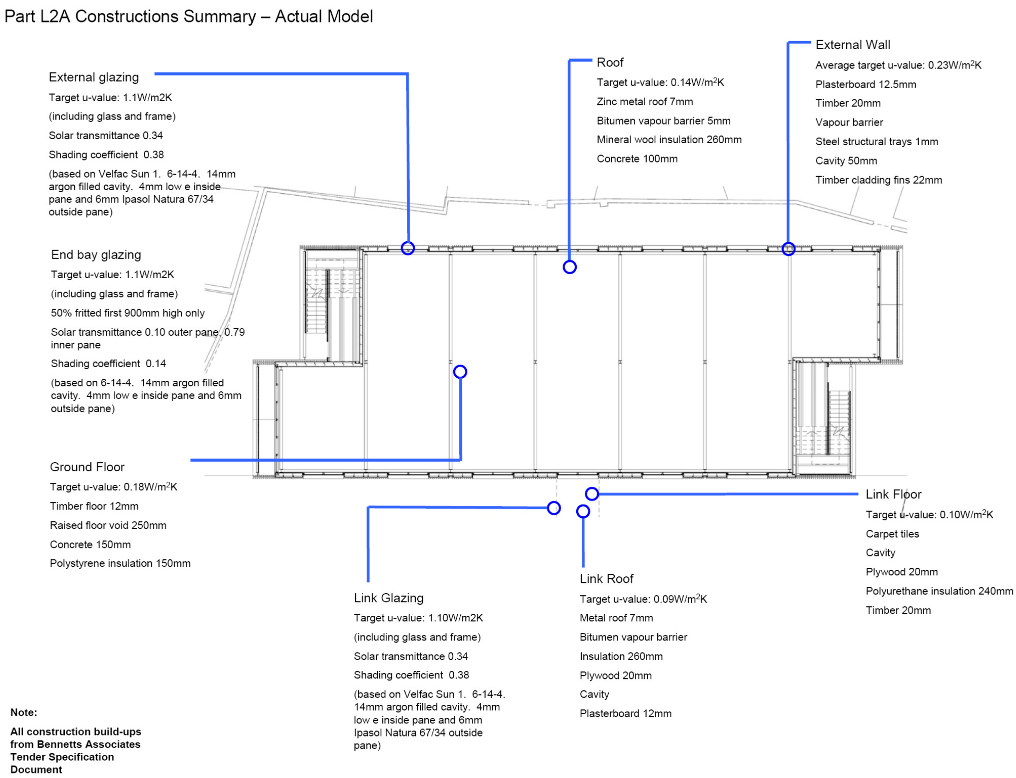

Fig. 2 Example Layout Drawing of the Building

As shown the figure 1 and 2 above, the building project in the case study is a newly built two storey open-plan office. Open plan offices were designed to allow more work spaces and place more occupants within them. It was also anticipated that the layout of the office needed to be made more adaptable to future changes in working practices making future churn faster to implement. But most importantly, open space offices also became part of the energy conservation strategy as only one centralized area was being heated, or cooled, and lighted. The design of the new office was based on the aspiration for a high quality architectural design, visual transparency from inside to out and a profile in keeping with the surrounding landscape.

The following table presents the internal design condition that was used in this office. It is formed from various guides and codes of practice for naturally ventilated offices.

Building type	**Air Temperature**	**Min. air supply rate (l/s/person)**	**Maintained Illuminance (Lux)**	**Daylight Factor**	**Noise Rating (NR)**
Natural Ventilated office	23 – 27 °C	8	300- 500	2 - 5%	30 - 35

Internal design criteria was used as such in an endeavour to minimise energy consumption for the internal design criteria, but at the same times meet the CIBSE recommendations for a naturally ventilated building.

The energy profile of this office building is shown in the figure below.

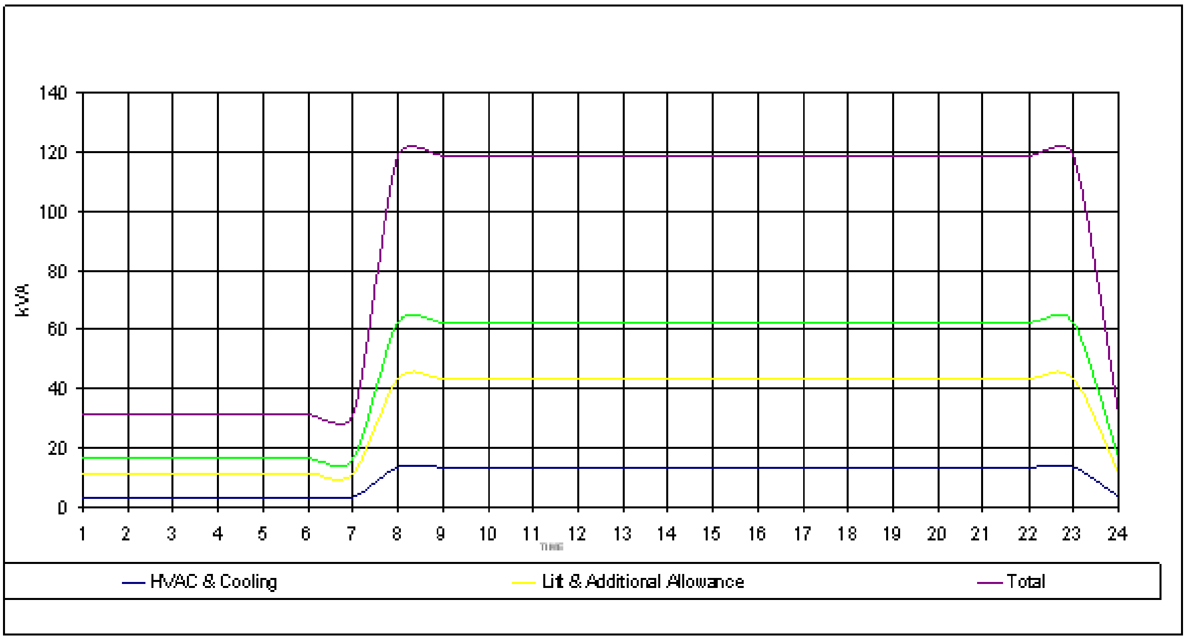

Fig. 3 Offices Electric Load Profile.

6 Analysis and Results

6.1 Energy Meters and Sub-metering

Energy meters might be useful instruments for gaining energy conservation awareness as they will provide the building operators and occupier's sufficient information for accurately monitoring the energy consumption. They provide building operators a clear figure of how much energy is being used and how energy consumption differs across the zones in the building. The effect of action taken to reduce energy usage is easily determined and this may encourage yet more energy efficient practices to be adopted. Information gathered from meters might also be used for energy certification and benchmarking. Part L building regulation requires that reasonable provision would be to enable at least 90% of the estimated annual energy consumption of each fuel to be accounted for.

Regarding the energy meter and sub-meter in this case study, meters were installed in the incoming services which included individual meters to directly measure total electricity, gas, oil and LPG consumed within the building. Additional sub-metering was provided for final electrical distribution boards, and motor control centres which provided power to fans, pumps and boiler installations.

Installing meters and sub-meters in this project might provide potential benefit to energy conservation. However, this potential will only be turned into real benefits if the awareness of the potential energy savings are themselves turned into actions.

6.2 Electrical System

Various methods can be used to conserve energy in electrical services such as: Demand Side Management and PF (Power Factor) Management. Demand side management is implemented through the use of energy efficient equipment such as energy efficient luminaries.

Power Factor (PF) is used to improve the power factor of electrical installation to achieve a power factor of at least 0.95. This is ensured through the installation of an Intelligent Power Factor Controller.

6.3 Ventilation Strategy

With the advent of the concept of efficient energy use, focus has shifted towards buildings becoming more air tight and having lower levels of ventilation. This is due to the fact that as buildings become better insulated and conducted heat loss is reduced, the proportion of heating and air conditioning load due to ventilation has increased and may offer the largest scope for reducing energy demand. It has also been shown that increased levels of ventilation improve performance of occupants.

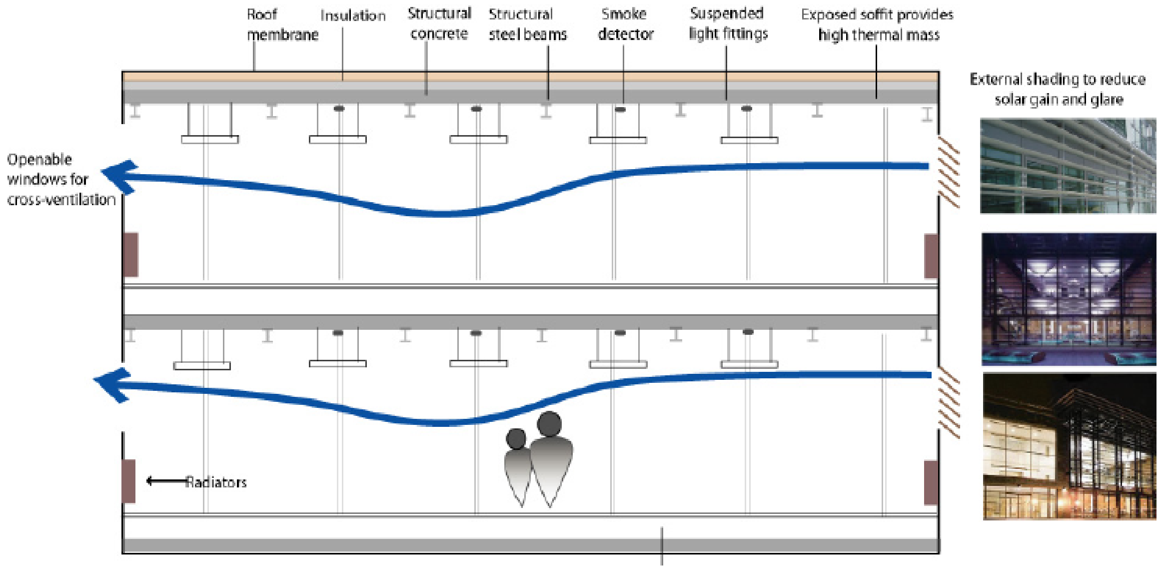

Fig. 4 A Natural Ventilation Environmental Strategy

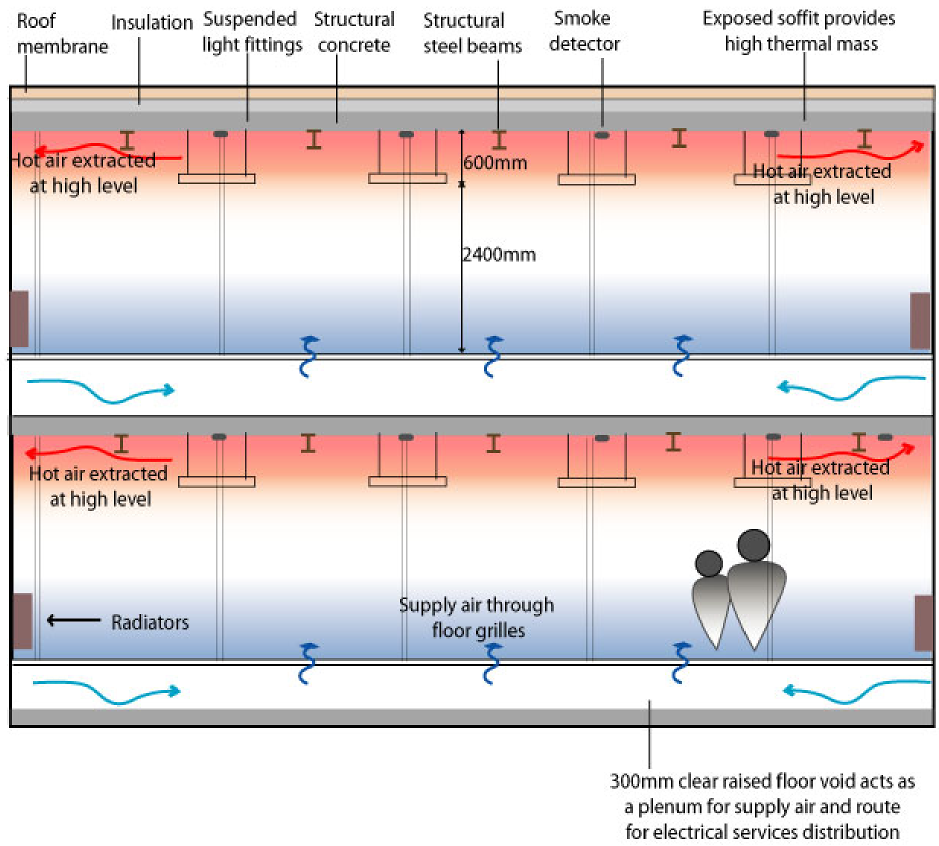

Fig. 5 B Mechanical Ventilation Energy Conservation Strategy

This office building was equipped with both natural and mechanical ventilation as shown on the above figure. Natural cross ventilation during periods of suitable ambient conditions was provided via opening windows and trickle vents. When the ambient conditions were not suitable to enhance the thermal comfort levels of the internal occupied zones, a mechanical ventilation system comprising of two supplies and extract of dedicated air handling units located adjacent the external stair cores will discharge supply air to the office via a pressurised floor void and displacement grilles. The air handling units provide a constant 19^{o}C air supply. The air handling unit (AHU) is also provided with a heat recovery system to reclaim energy from the exhausted air.

The WC areas are mechanically ventilated via the extract ductwork system with branches serving each toilet cubicle. Each toilet core is provided with a twin fan extract unit which is located at high level. The system will operate when the toilet is occupied - this being sensed by PIR detectors complete with variable run-on timer facility.

Tempered supply air will be introduced to the office spaces via the floor void which will serve as a supply air plenum integrated with the flooring system. Air will then be discharged into the office area through floor mounted swirl diffusers. This air will then be mixed with air within the office space to maintain the required conditions. Floor grilles are made available and distributed across the two office floors. The system will be fully flexible with the ability to relocate the floor tiles as required whilst maintaining the integrity of the floor plenum.

Return air is drawn back into the system through the return air ductwork set at high level within each office floor via return air grilles.

6.4 Lighting and Day-lighting

The lighting in this office project incorporated daylighting and this was was considered early in the design stage; because it is at this stage the major decisions affecting the daylighting are made and any significant changes to the daylighting in the later stage are much more difficult and costly to adopt. Many buildings have good natural lighting and ventilation, but may suffer related problems of glare, excess solar gain, heat loss and draughts. This building was designed to achieve maximum optimisation between getting good natural lighting but at the same time reducing glare, and excess solar gain effects.

6.4.1 Day-lighting

Daylight makes an important contribution to the light levels and atmosphere of an interior and may provide sufficient illumination for substantial periods in some offices, avoiding the need to use the electric lighting. The daylighting aspects of a building are determined primarily by the form of the building and its windows, factors which are fixed at the design stage.

Through the careful designing of building envelopes, the daylighting levels show that this building has a relatively good daylight factor. This indicates that the electrical lighting load within the thermal model can be reduced assuming that artificial lighting will not be switched on constantly. The lighting load has therefore dropped to 10W/m^2 in the office areas.

To complement the daylighting, the building energy conservation features are also enhanced by the use of energy efficient artificial lighting installation. The energy efficiency of an artificial lighting installation depends on:

- The efficiency of the various components of the system: lamps, ballasts, luminaires,
- The way in which they are used, often strongly influenced by the control system and the daylight availability

A 26 mm diameter fluorescent tube was used instead of a 38 mm tube. These slimmer lamps produce approximately the same light output as the larger diameter lamps of the same length and colour temperature, but consume about 8% less energy. Apart from the lamp, reflectors and control gear have been carefully selected to make the artificial lighting more efficient. In some areas the overhead lighting is reduced, as it is anticipated that individual task lighting will be used at some workspaces.

The general lighting comprises of high frequency low energy fluorescent lamps to improve energy efficiency and keep maintenance costs to a minimum. Individual office lighting is provided with pendant luminaries utilising direct / indirect light distribution. In general lighting which complies with CIBSE LG7 is used in open plan office. Metal halide and low voltage halogen luminaries are used for decorative effect and accent lighting in the reception areas.

To balance between achieving a good daylighting factor but at the same time preventing excessive over heating in summer, the control systems ensure that automatically controlled blinds and window coverings operate on all solar exposed windows during appropriate times of the day. The control system also operates the blinds and windows when rooms are not in use to block excessive direct sunlight.

6.4.2 Lighting Control System

Four methods of lighting control are used:

- Time-based control,
- Daylight-linked control,
- Occupancy-linked control,
- Localised switching.

Occupancy sensing has been shown to be an effective means of reducing lighting energy use in offices [3, 6, 12]. Time scheduling can also save significant energy in similar ways in large spaces [16]. Time scheduling saved from 0.7 to 6.6 percent or an average of about 5 percent. Occupant sensors in similar areas saved from 9.0 to 14.6 percent, with an average of about 10 percent [4, 10, 11]

Further improvements in energy efficiency are achieved by using automatic sensing of daylight levels and linking this to occupancy levels in order to reduce the illuminance level and the number of hours electric lighting was used. Automatic sensing also allowed the switching off of electric lighting when a space was unoccupied. Therefore, the lighting control strategy for a particular space in this building depended on the daylight availability and the type and pattern of occupation.

Localised switching is used where only part of a large space requires the electric lighting to be switched on, either because the other parts are unoccupied or because the daylight there is adequate. In addition localised switching will increase user satisfaction by allowing occupants to have more control over their working environment through the use of localised switches.

Studies in open plan offices have shown wide variations in user preference for lighting with some occupants switching their lighting on under almost all conditions and others doing so only on rare occasions. This produces noticeable energy savings compared with the common situation where the lighting in the entire space is controlled with a single switch.

For spaces with negligible daylighting, a combination of time switching and localised switching cover most situations, although care is necessary to ensure that the lighting is not automatically switched off to leave dangerous blackout conditions. For installations with sparse and intermittent occupancy, localised switching will eliminate the need for the whole space to be lit when only a small part is in use; occupancy detectors are particularly suitable for such spaces.

7 Heating System

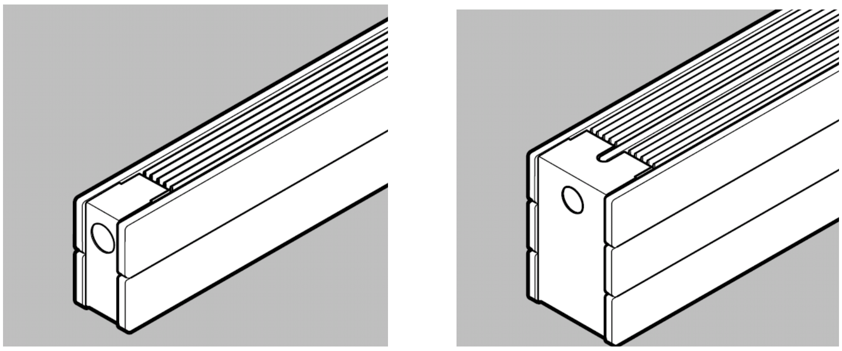

Fig. 6 Panel Radiator for General Heating

Low temperature hot water for heating was used and it was generated by 2 No 83kW low NOx atmospheric wall hung gas fired room sealed boilers located within the office building cupboard. Balanced flues terminate through the external wall of the office. Air for combustion and plant room ventilation is provided via louvers located in the external wall.

System make-up and pressure is maintained by a pressurisation unit. The unit is provided with high and low pressure switches and an expansion vessel to inhibit the boiler operation in the event of an alarm. The primary heating pump set is used to maintain the minimum flow through the boilers and overcome the primary circuit resistance. Separate pumped distribution circuits are provided to facilitate a constant temperature circuit serving the heater batteries of the air handling plant and a compensated circuit to serve the radiators.

Steel panel radiators as shown in the above figure 6 are used for general heating. Each radiator is provided by a thermostatic valve on the flow connection and a lockshield valve on the return.

8 Insulation and Building Fabric

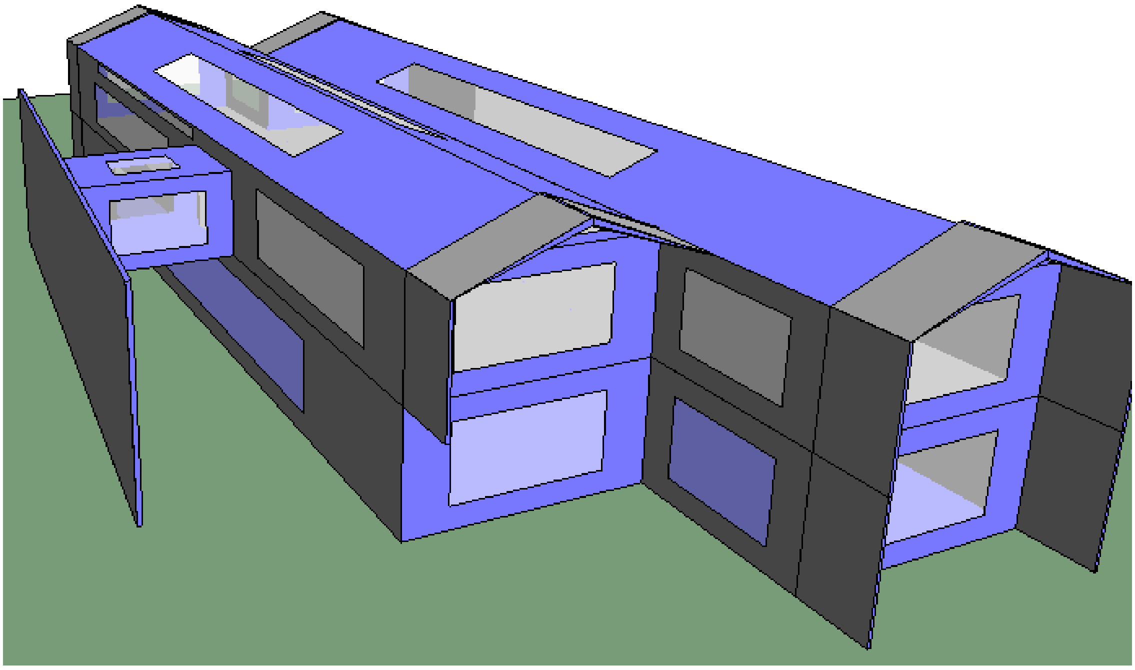

Fig. 7 Building Envelope with Glazing 20%, Roof Areas and Roof Lights 40% of Total Façade Areas

The building fabric and envelope has an important role to play in reducing the demands placed upon the energy consuming M&E system. As part of an integrated energy efficient design to achieve energy conservation, exposed (and semi-exposed) elements were insulated to produce a highly insulated building envelope. Filling cavity walls with insulation was used in the first instance wherever possible as it is one of the most cost-effective options. Roof and floor slab insulation (including slab edge insulation) were particularly important as well. In the pitched roofs, at least 200 mm of insulation was used, laid in two layers, one between the joists and the second across the joists to prevent thermal bridging. A gap at the eaves allowed ventilation and prevented condensation. Battens are used to raise access walkways above the insulation.

Improvements in glazing technologies over recent years provided enormous opportunities in this building project. Quite significant reductions in U values can now be readily achieved compared with few years ago. This makes it possible to achieve a good daylighting factor but at the same time reduce the potential for overheating in summer. The building fabric was been chosen to meet the requirement of revised U values, air leakage and heat gain requirements as required by the UK Building Regulations.

Attention was also paid to avoiding thermal bridging. Heat loss from thermal bridging occurs where one element of a building is more poorly insulated, and thus colder, than the other parts. Thermal bridges are also associated with condensation and it has been anticipated that this will occur around windows, doors, and at the junctions between external walls, floors and roofs.

The thermal bridging is avoided by maintaining continuity of insulation. Where this is not possible, overlap the insulating layers techniques is used to prevent a direct thermal bridgeand this is enhanced by the use a material with good insulating properties to bridge the gap between the layers.

Background air leakage was minimised and controllable ventilation was provided by means of purpose-designed openings. It has been identified that the main air leakage paths are:

- Joints around components, e.g. windows
- gaps between one building element and another
- Holes where services pass through the construction.

In considering these leakage paths, care was taken to ensure that these areas were all well sealed. Minimum U values for the materials used in the various elements of the building fabric have been achieved.

External shading is used to prevent solar radiation from entering into the buildings and reduces the cooling load, results to better control of overheating and indoor temperatures. Space cooling load may be reduced by 30% due to proper shading. The office provides an element of shading to the north nest of the site. The south east corner is affected by overshadowing primarily during the early morning in all seasons.

9 Discussion and Conclusions

The introduction of the Building Regulation legislation has made it necessary for buildings in the UK to have a better energy design and performance than previously and there is an emphasis on the use more efficient M&E systems in building to achieve compliance. Approved document Part L2A is intended for new non-domestic buildings which is applicable to this building in the case study.

The office building in case study has shown the compliance with the building regulation and conservation of energy. Energy conservation in office buildings and the compliance with Building Regulations are achieved through the early incorporation into the building design of energy efficiency measures. A large array of solutions exist to achieve energy conservation in buildings. Design has to consider flexibility along with the ideal design solutions and must allow for the building to be satisfactorily commissioned and maintained.

These latter and former criteria were incorporated into the design of the building in case study by use of the following measures

- Ventilation system with a good high heat recovery system.
- Limiting the heat loss and gain through the fabric by enhancing levels of insulation of the building fabric to achieve lower U-Values.
- Limiting the heat loss and gain through the fabric of the building by improving air tightness to minimise any uncontrolled air leakage.
- Providing space heating and hot water systems which were energy efficient.
- Improve daylight levels and reduce reliance on artificial lighting energy. Artificial lighting energy is achieved thorough provision of lighting control systems and appropriate lamps so that energy can be used efficiently.
- Improve the control and monitoring of mechanical heating and ventilation systems to identify use trends and future energy saving strategies.

Results from previous studies suggest that the key feature of an energy efficient building as a meaningful way to contribute to energy conservation is expected [2,9]. Efficiency gains in buildings are likely to provide the greatest energy reductions of any sector of western society and in many cases might be the most economical option.

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