Façade engineering and building physics

High performance - low impact Ropemaker Place, London, UK

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Abstract

Facade engineering is gaining importance in this time of recession and climate change, two issues which will continue to impact on the way we go about our business as building designers.

One of the implications of climate change is the way our buildings increasingly need to deliver high performance and low impact. The effects are felt in the form of legislation, but also as a growing demand in the marketplace for 'rated buildings'.

Façade engineering is an essential component of integrated design and delivery. The discipline is potentially maximising value for clients and offering the broad technical approach which is needed for the realisation of sustainable buildings to ever more challenging programmes and budgets in a global market.

This paper discusses the value of early stage facade engineering, using as a case study, the Ropemaker Place project by Arup Associates. A relatively simple concept of window orientation for control of solar gains is rendered feasible through a series of design studies, building physics assessments, and early stage specialist contractor buy-in. The result is a high performance architectural building envelope and a BREEAM Excellent rated, commercially successful building.

Background

Façade Engineering is a relatively new discipline, which is gaining importance in a time where recession and climate change are factors leading to increasing focus on the need for an integrated approach to the design and procurement of buildings.

Technological developments and the way buildings are procured means that success often depends on specialist input across a broad spectrum, which some twenty years

ago led to the creation of the first façade engineering practices.

This paper discusses the potential of early stage façade engineering input in delivering ambitious designs and high performance.

Through the use of a case study the emphasis is on building physics and the way the building energy strategy is addressed, but the considerations will generally apply to other aspects as well. The fundamental issue is that integrated design facilitates high performance - low impact and depends on the ability of client and design team to pay due attention to detail from the very early design stages.

The case study project, Ropemaker Place, is a commercial development near Moorgate in the City of London, UK. The developer is British Land, Arup Associates are the designers, and the BREEAM Excellent rated project achieved Practical Completion in May 2009.

Incorporating offices and retail facilities, the development builds on British Land's ethos of sustainable design and the importance of flexibility for modern office buildings. The building was completed on time and under budget.

Additional context is offered by comparison with the Plantation Place development, completed just a few years earlier by the same combination of developer and design team.

When a previous Ropemaker Place scheme developed by a different design team was abandoned by the client, Arup Associates were brought in because of the successful collaboration on the Plantation Place development.

The Ropemaker façade design is an excellent example of the integration of architectural treatment with environmental performance; the design team created a bespoke tilting façade system which reduces energy for cooling by up to 27 per cent compared with a reference flat façade.

The subtly changing colour and rhythmic expression of the façade present a dynamic canvas of reflectivity and tone, while the projecting arrays also provide the integrated solar shading as the windows 'turn their backs' to the sun and thereby significantly reduce solar gain and consequent cooling loads. The building is composed of six large scale interlocking cubic forms, rising up as a series of garden terraces. These roof terraces are both a remarkable natural amenity for the people who occupy the building and a bio-diverse habitat of flora, fauna, insects and birds.

They have directly contributed to the attractiveness of this building to the tenant over a plethora of available alternative developments

Design Team

Arup Associates is a multi-disciplinary design practice. The Ropemaker Place project was set up with input from specialists in Arup Facade Engineering as a repeat of a successful formula adopted in connection with the Plantation Place Project executed a few years earlier. The facade concept was developed in close collaboration across the disciplines covering architecture, environmental strategy, facade detailing, buildability, building physics, and procurement including costing.

The building regulations stipulate requirements in terms of the energy consumption of buildings. In the case of Ropemaker Place, the design targets and the demonstration of compliance were based on the national Simplified Building Energy Model (SBEM).

The performance of a proposed design is assessed in terms of carbon emissions and compared with a project-specific target. The target is given by a notional building with the same massing as the proposed model, building fabric based on minimum standards, given ratios of window/wall, and a range of other relevant parameters.

The target and the design rating are calculated on the basis of standardised occupancy profiles. This means that the design rating is not related to the expected actual use of the building, which can be markedly different. This difference is addressed by operational ratings once the building is in use.

In the case of the Ropemaker Place project, the client and design team did not just settle for the SBEM code compliance test when developing the design. Three distinct scenarios were developed with a view to providing a building, which could be operated efficiently in a series of regimes. (1) Code Compliance (SBEM) scenario. The SBEM scenario was mandatory and assessments were carried out to gauge the impact of proposed design features and options. (2) Client's Brief scenario. In addition to the standard compliance scenario, the design was developed in accordance with the client's brief, which was based on market standards and the expectations of likely tenants.

For example, the occupancy profile would allow for trading floors as frequently required in City offices. (3) Low Energy Tenant scenario. The building was prepared for efficient operation in a low energy mode as a way of catering for tenants with sustainability aspirations - tenants who would be attracted to a sustainable design and who would be willing to adjust their building operation to curb carbon emissions.

Compared with the highly successful Plantation Place project, the facade budget was limited. Consequently, the design team were not in a position to adopt the advanced facade concepts developed for the same client a few years earlier. It was clear that very high performance would be required and consequently the challenge was to deliver high performance and appealing architecture to suit the budget and meet the sustainability targets.

Façade Concept

The facade concept for the Ropemaker Place project takes inspiration from the classic bay window. While the concept is informed by and expresses the solar control strategy, the design was enabled through early stage facade engineering and appropriate building physics analysis combined with multi-scenario, multi-criteria building energy simulation.

The Plantation Place development featured a series of advanced facade solutions. The lower levels are 'sealed' (i.e. no openable windows) with stone fins to fit into the urban fabric of the City of London. The massing of the buildings is informed by planning policies, including rights to views of the St Paul's Cathedral. The result is that the buildings step back and the floorplates of the top levels are less deep. The facade to the upper floors is a double skin system with openable windows in the inner facade and automated solar shading device in the cavity between the two skins.

The fully glazed outer skin is shingled, which means that the glass panels are tilted slightly with open joints between them. The inner curtain wall facade is not highly glazed by

London standards, but the outer skin gives the top storeys of the building a highly glazed look and feel, with reflection of the sky bringing a certain 'lightness' to the big elevations when seen from the streets below.

Besides the architectural aspect of the outer skin, it also serves to shield the shading device from the wind. Without the outer screen the automated external venetian blinds would have been exposed to the wind and there would have been situations where they could not be deployed when needed.

The double skin arrangement solves this problem and the control system is fairly sophisticated with zoning according to solar exposure and shadowing.

The double skin also serves to shield the openable windows from the wind and deals with the problem of natural ventilation at height. The openable windows have been built in as a future proofing measure or an optional environmental feature. The building is currently fully conditioned but can be operated in mixed mode.

The Ropemaker Place facade budget did not allow for a complex multilayered facade and the design team responded by letting the geometry of a 'single skin' facade respond to the solar exposure of the different elevations. The facade is not excessively glazed and the windows are rotated away from the sun - east and west facing windows are rotated towards the north around a vertical axis, while the south facing windows are rotated around a horizontal axis, leaning forward.

The rotation means that an element of self-shading is achieved, similar to what would have been achieved by means of fins and overhangs. A second order effect is the reduction in solar transmission of the glazing for extended periods of time due to the resulting increase in the solar angle of incidence.

The bay window design inevitably leads to an increase in thermal transmittance due to the greater developed transmission area and, more importantly, the bay window ('collar') framing leading to some degree of linear and point thermal losses. Previous research has shown that relatively minor changes to the thermal transmission of the building envelope may not be critical for a commercial building with relatively high internal gains. The design team carried out a series of studies to assess the overall energy performance, taking into account the expected increase in thermal transmittance and gauging the combined effect in heating and cooling mode.

Early Stage Façade Engineering

The facade engineering input during the concept stages was crucial in terms of testing the feasibility of the proposed design and exploring ideas in informed dialogue with selected specialist cladding contractors.

The initial idea, based on considerations regarding solar shading and reduction of solar gains was quickly interpreted and presented as a series of conceptual hand sketches in an effort to gauge the complexity and the viability of the concept.

The conceptual studies were linked with building physics input - initially as general considerations and gradually as more specific estimates of required and achievable thermal and solar performance.

Clearly the single biggest impact on solar gains is given by factors such as window size and orientation and this is where the specialist input blended with the architecture.

The involvement of facade engineers resulted in a series of constructive meetings where 'pros and cons' were tabled and discussed openly. The work that went into the conceptual studies gave sufficient confidence to move into detailed design. This is significant as the achievable thermal and solar performance of the facade was pivotal in terms of the overall energy (and sustainability) strategy of the development.

Specialist Contractor Buy-In and Collaboration

From the early design stages the design team collaborated with specialist sub contractors, who were invited to discuss the proposed design concept. Engaging in such buy-in sessions is an important way of checking technical feasibility and budget pricing before the design is progressed in detail. It is also a way of gauging the willingness of the market players to work to achieve the desired result.

In the case of Ropemaker Place, the design team met with a selected specialist contractor who committed resources to assessing buildability and carrying out detailed thermal analysis on a number of key details. These studies in turn fed into the broader energy assessment exercises carried out by the design team.

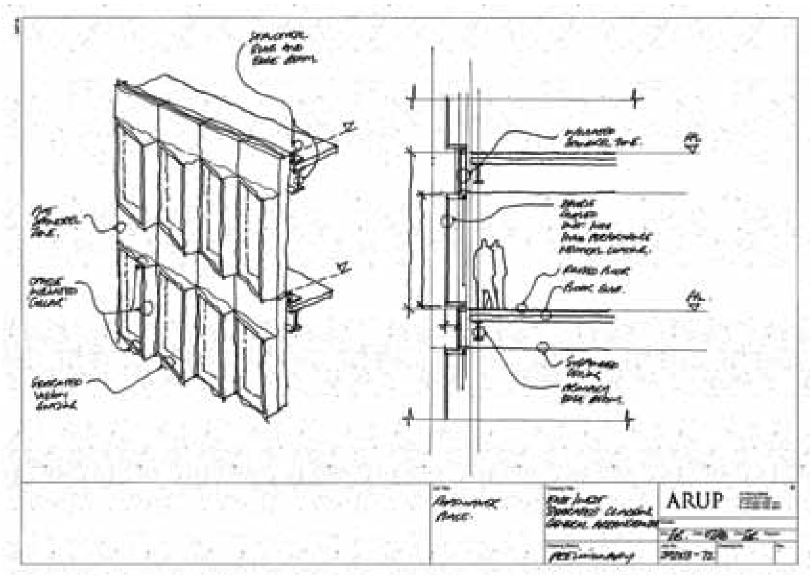
Evidence-Based Design

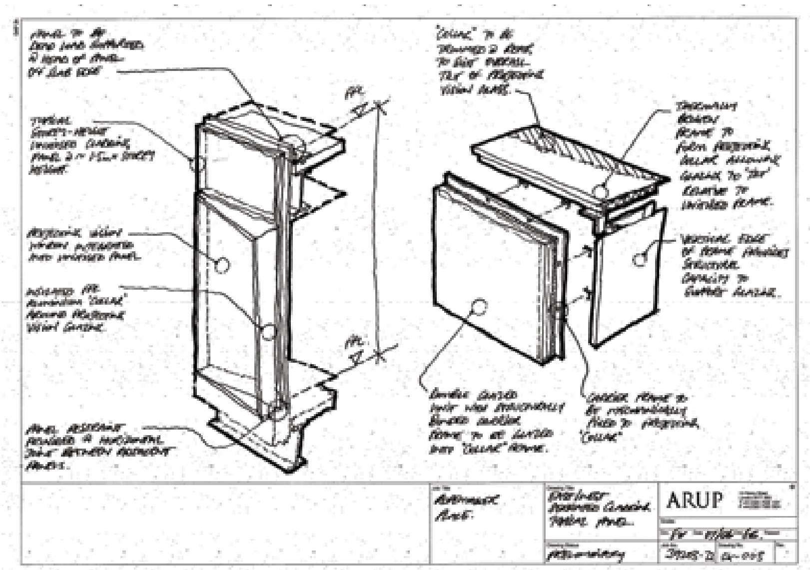
A series of studies were undertaken to evaluate the performance of the proposed concept. Detailed dynamic thermal simulations were carried out for the different orientations of the building, the facade concept was benchmarked against three different facade types, and three different occupancy scenarios. Sensitivity studies were carried out to determine the effect of the total solar energy transmittance (g-value) of the glazing.

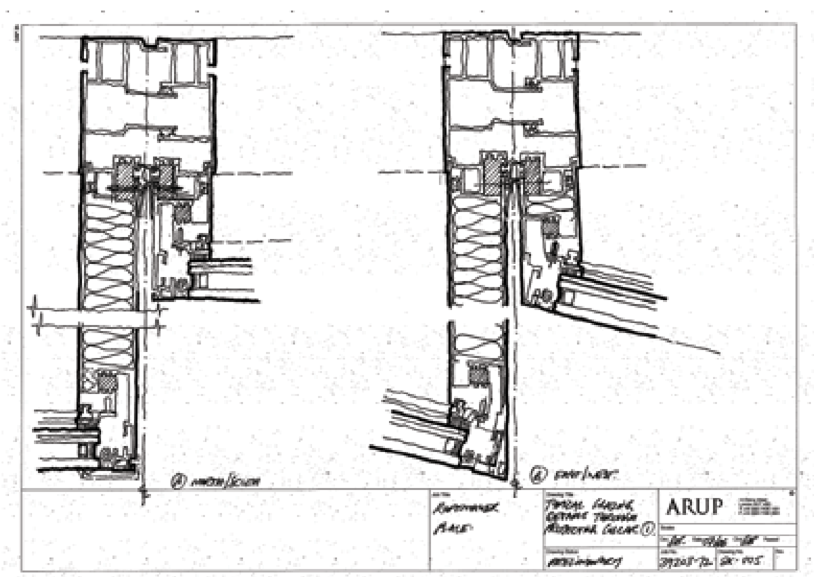
The project is an example of evidence-based design in that different concepts are tested for different scenarios as an intrinsic part of the decision-making process. The proposed design was referred to as the serrated facade and it was benchmarked against (A) a flat - or flush - facade of similar build-up and layout, (B) the facade from the previous, abandoned scheme, and (C) the double skin facade from the Plantation Place project, representing the state-of-the-art.

The purpose of this paper is not to describe in detail the analyses and the outcomes of the work but to highlight the value of the integrated approach to design, and the impact of early stage facade engineering.

Through a sequence of appropriate analyses, coupled with studies of buildability and architectural concepts, the design team gained the necessary confidence that the required







performance would be delivered in practice. Armed with this evidence the project could be presented to the client and the dialogue with the specialist contractor could advance to the next stage without having to readdress the concept.

The performance of the façade was assessed in terms of the predicted annual energy consumption and the peak loads in the perimeter zone of the building. The modelled depth of the perimeter zone was varied in accordance with the different design scenarios.

The effect of the rotation of the windows varies with orientation and scenarios, but the annual energy consumption for cooling is reduced in all cases.

This paper discusses specifically the approach to façade design and the importance of early stage integration. Similar work was undertaken in other areas with a view to enhancing the general sustainability of the project.

The commitment of client and design team resulted in a scheme with high performance and low environmental impact. The sustainability of the building was demonstrated though a BREEAM Excellent rating, adding significant value to the property. The property also received LEED Platinum PreQualification for Core&Shell, a first outside of the USA.

The developer British Land turns sustainability to business and the property was marketed on its performance. The anchor tenants have stated that the property had been chosen because of its sustainability rating.

Society of Façade Engineering

In 2003, a group of professionals established the Society of Façade Engineering (SFE) in recognition of the need to 'regulate' the industry and introduce a system of accreditation.

The SFE was inaugurated in 2004 as a Society under the Chartered Institution for Building Services Engineers (CIBSE), supported by the Institution of Structural Engineers (IStructE) and the Royal Institute of British Architects (RIBA).

The Society was initially UK-centric - mainly because of the people involved in the initiative and the fact that SFE was set up in London. It was, however, always the intention to establish

an international society. The membership is international and the Society is experiencing significant growth in the regions - Notably the Middle East where the SFE was launched around the beginning of 2009. The Society is still in its infancy with approximately 250 members, but the interest in the Society is building and the membership is expected to multiply through regional initiatives as well as a concerted effort to reach out to the membership of the supporting institutions. There are a number of benefits of membership, such as: recognised professional status (Associate; Member - MSFE; or Fellow - FSFE); enhanced career opportunities; professional networking; events; magazine; technical forum - to name but a few.

Subscription is free to all existing members of CIBSE, whereas non-CIBSE members get affiliate CIBSE membership when joining the SFE and get the benefits of CIBSE membership, including free online access to publications. Members are actively encouraged to contribute information to the Elevation Magazine of the SFE and take part in the activities coordinated through the SFE Steering Committee.

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