CIB TG 16, *Sustainable Construction*, Tampa, Florida, USA, November 6–9, 1994.

# THE ENVIRONMENTAL IMPACTS OF CLADDING SYSTEMS FOR THE FACADES OF BUILDINGS

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## SUMMARY

This paper presents part of an ongoing research programme into the Environmental Life Cycle of buildings being undertaken by the University of Brighton. It concentrates on the environmental impacts of cladding systems analysing the results of an attitude survey undertaken of designers and manufacturers and demonstrating the environmental impact of two cladding systems through case studies.

## INTRODUCTION

All buildings have an impact on the environment by virtue of the resources they consume, the pollution they cause and by virtue of their presence within the natural landscape.

Natural resources are consumed in the materials of construction and in the energy used to manufacture and transport the building components and to heat, cool and light the building during its operation. Consideration must be given both to the sustainability of these resources and the impact that removing them has on the local environment.

Further environmental impacts are experienced at the end of the useful life of the building when it is demolished. Transient environmental impacts are experienced during the demolition process, the materials will then need to be disposed of or may have a positive affect on the environment by being recycled and reducing the demand for new materials.

The consumption of energy in the form of fossil fuels produces pollution in the form of the products of combustion such as carbon dioxide, sulphur dioxide etc. In addition the winning of the raw materials often causes further pollution in the form of dust, noise and vibrations.

The construction of a building, whether in an urban or rural situation, clearly changes the environment in which it stands. The aesthetic of the building has considerable impact on those who see the building either as users or passers by. Many architectural and planning debates take place on this account which is an important environmental impact of the building. Cladding systems, which are the main focus of this paper, are vital to the aesthetic of the building and have great impact in this way.

## ENVIRONMENTAL LIFE CYCLE OF BUILDINGS

In order to evaluate the environmental impact of a building it is necessary to consider its effect on the environment throughout its life cycle, from the winning of the raw materials to its eventual demolition and disposal of the demolished materials. This cradle to grave assessment needs to be carried out for individual materials and components as well as for the building as a whole.

Life cycle assessment has been advocated for many years as a technique for determining the true cost of a building or installation. It requires that the operating and maintenance costs of different design solutions are considered at an early stage and not only the initial purchase and installation cost.

However, even with a factor such as financial cost which can easily be quantified, there is often conflict within the parties involved with the building contract as to the priorities of cost within the project. Priorities may simply be for lowest initial cost, although additional costs may be accepted for better materials required for a prestigious building or for energy efficiency in operation or speed of construction etc.

In the same way as the life cycle cost of the building can be analysed so too can the life cycle energy consumption of the building. This will include energy consumption in:-

Winning raw materials
Manufacture of building materials
Construction on site
Operation of the building
Maintenance
Refurbishment
Demolition
Recycling

and all the elements of transport and component manufacture between and within these stages.

In general terms the energy life cycle can be subdivided into three parts, prior to occupation, throughout the useful life of the building and finally, demolition and disposal. The energy consumed prior to occupation is termed the Embodied Energy which hitherto has received little attention compared with the research undertaken to determine energy consumption during operation of the building.

As energy consumption during the occupation of buildings is being reduced by improving insulation standards and building refurbishment cycles are becoming shorter so the embodied energy of the building materials are becoming more significant. Recent publications of research on the subject (Connaughton 1990; Krogh and Hansen 1994; Miller and Humby 1994) demonstrate current activity in the field.

Consideration of the environmental impacts at the end of the useful life of the building are also the subject of recent research (Lawson 1994; Allwinkle and Stembridge 1994).

## AIM OF THE PAPER

The research has been focussed on the analysis of cladding systems used to construct the external walls of a building. The paper analyses the attitudes of key designers and manufacturers of these systems from their responses to a postal questionnaire. Further it identifies some of the environmental impacts related to cladding systems using the case studies of two modern office blocks.

The external envelope of a building is of prime importance when considering the environmental impact of a building. In particular the external walls provide the main element of aesthetic impact of the building on its surroundings. They are also key elements of the envelope as a climate modifier affecting the flow of both heat and light and consequently the resulting energy required to maintain comfort conditions within the building.

In the case of cladding systems the importance of the environmental issues is complemented by the fact that they can represent up to 20% of the cost of the building project

## QUESTIONNAIRE

The questionnaire was formulated in order to identify the current thinking and the existing level of consideration given to the environmental impact of buildings by the construction industry. It was sent to a total of 40 building designers and manufacturers of cladding systems within the UK.

The sample was made up of 24 designers and 16 manufacturers of which 16 and 12 respectively replied to the questionnaire. This represented a total response rate of 70% which in itself demonstrates something of the current interest of the industry in environmental aspects.

The responses to the questionnaire have been analysed under the headings of General Environmental Aspects and Environmental Priorities.

## GENERAL ENVIRONMENTAL ASPECTS

The questionnaire addressed the general consideration of environmental issues by the respondents and their companies. It showed that nearly all design practices have an environmental policy and that some of the larger practices have environmental committees that set down strict criteria to influence all aspects of their work.

In general the designers see the environmental impact of the facade of the building as its ability to temper the internal environment.

Typical responses demonstrate the designer's attitude:-

*To reduce the reliance on non sustainable energy sources.*

*Improve quality of life for building inhabitants including more personal / local control of the environment.*

*The hope is that people will then take a little of the ethos home with them*

The latter comment demonstrates a real will that the new building should, through its design, be used as a means of raising the awareness of building users to environmental issues.

One of the respondents stated that there was now a greater tendency for the clients of new developments also to be the end user. Under these circumstances there is greater importance attached to life cycle cost assessments of the building.

A greater consideration of the total life cycle of the building must lead to greater awareness of the environmental issues throughout the life cycle.

In general cladding manufacturers believe that they have minimal effect on the environmental impact of their systems because they are brought in too late in the design process. At this stage they are not able to influence the design philosophies.

It is clear that these responses are directed at the influence that the cladding manufacturers might have on the building as a finished product and on its operation. They do not consider the environmental impacts of producing the cladding materials.

## ENVIRONMENTAL PRIORITIES

Respondents to the questionnaire were asked to assess their priority rating of eight different issues that affect the environment:-

Material production
Material durability
Reduced energy consumption during operation
Solar shading
Natural Ventilation
Natural Daylighting
Maintenance
Recyclability of components

Each respondent assessed these issues as being of low, medium or high priority of significance to environmental impact. The responses were then analysed and weighted numerically in order to produce a rank order of priorities.

Unfortunately not all respondents completed the whole list of priorities but each analysis is based on no less than 10 responses for each factor. The ranking being evaluated based on a percentage of the total possible score for each issue.

The relative ranking and percentage scores are given in Table 1.

Table 1. Rank order for priorities of environmental issues.

| DESIGNERS | | MANUFACTURERS | |
|---|---|---|---|
| Daylight | 83% | Daylight | 90% |
| Maintenance | 83% | Reduced Energy | 90% |
| Solar Shading | 77% | Maintenance | 85% |
| Reduced Energy | 76% | Solar Shading | 85% |
| Durability | 76% | Durability | 80% |
| Natural Vent. | 66% | Natural Vent. | 76% |
| Recyclability | 56% | Recylability | 48% |
| Material Prod. | 45% | Material Prod. | 48% |

The percentage figures have little more importance than that they allow a rank order to be drawn up. However it is important to note that the rank order is almost identical for both designers and manufacturers.

The significant factor from these rankings is that Daylighting, Reduced energy consumption during operation and Solar shading, all occur within the first four rankings for both sets of respondents. This demonstrates that the current thinking and priority is for the cladding system to affect the resulting internal environment of the building. The highest consideration is given to the environmental aspects of owning and operating the building.

Similarly significant is that the bottom two ranked issues on both lists are recyclability and material production, demonstrating the lower priority given to the total environmental life cycle where the materials come from, the embodied energy and the ability to recycle at the end of the useful life of the building.

Responses elsewhere in the questionnaire showed that embodied energy was considered to be an important issue for the future. They state that there is currently insufficient detailed information on which to base a rigorous assessment of embodied energy for a building. The basis for consideration at this stage is purely common sense and the small amount of published literature available.

It is considered that embodied energy issues are liable to become client led through public awareness and perhaps through European Community pressures.

Comments that were received with the questionnaire responses endorsed the low priority given to recycling of demolition materials. They stated that the costs of sorting and analysing materials far outweighed the cost of the material it was intended to replace and that there was a need for incentives and government in order for progress to be made.

## CASE STUDIES

The case studies have been selected to demonstrate environmental issues associated with the design, development and installation of building facades. They are based upon two Commercial office developments one, Minster Court, completed in 1990 and the second, Perpetual House, should be completed soon after this paper is delivered in December 1994.

The two cladding systems are very different, Minster Court being designed for visual impact in the centre of London whereas Perpetual House was designed to suit the typical stone and brick facing of a traditional English town whilst still housing a highly serviced office interior. The difficulties of comparing aesthetic environmental impact are therefore immediately evident.

## MINSTER COURT

Minster Court (fig. 1) is a 100,000 square metre development of three buildings set around a central glazed piazza located in the centre of London. The outline specification required an external wall system constructed of pre-insulated panels onto a steel structure framework. The outer face of the panels were to be of red polished granite supported in an aluminium frame. The total wall area of the project was approximately 37,000 square metres, 25,000 square metres of red granite panels and the rest hermetically sealed grey tinted solar control glass windows.

### Source of Materials

The granite selected for the panels at Minster Court was chosen from a source south of Sao Paolo in Brazil. It had to be won from a large outcrop, cut into handleable sizes to be transported overland to Rio de Janeiro and then by sea to Italy where it was cut into the required thicknesses. At this stage the quality of the stone could be inspected and graded before the selected material could be processed into panel sized sections ready for transportation to Gloucestershire in the South west of England for the final assembly of the panels before transportation and erection on the site in London.

The aluminium sections were extruded in Germany as were the solar control glass and the inner lining panels. All were transported to the Gloucestershire factory for assembly.

The preparation work necessary for the finished granite on Minster Court was considerable, processing from large pieces of stone into slabs, on to polishing and further cutting ready for panel assembly prior to site installation. There is also a tremendous wastage of material from raw stone before final selection for inclusion in the panels, not all of which can be adopted for other uses.

The transportation of the material and the machinery involved in the manufacturing processes all consume fossil fuels for their operation which results in depletion of natural resources and also the associated pollution of the products of combustion.

## PERPETUAL HOUSE

Perpetual House (fig. 2) is a 5,000 square metre development located adjacent to the river at Henley on Thames, approximately 40 miles west of London. Its external facade is based on local planning requirements to complement the surroundings and uses hand made bricks, roof tiles and reconstituted feature stone with a dry wall inner skin. The double glazed windows are openable for natur^al ventilation whenever possible and the building includes a chilled beam natural air move-ment cooling system.

The cl. lding for Perpetual House was primarily built up on site with only small elements of feature brick and stone lintels being pre-made in the factory. The bricks were all manufactured in Leicestershire England in a traditional kiln fired process. The reconstituted stone was manufactured off-site in the Midlands from sandstone and white cement. The larger stone components were set onto pre-cast concrete block supports for transportation and erection.

The winning of the raw materials for the bricks and mortars used on this building has its own environmental implications as do the manufacturing processes of brick making and cement production etc. In addition there are the implications of energy consumption for transport, however all of this was within the UK.

The double glazed aluminium windows are similar to Minster Court with sections assembled in the UK from extrusions processed in mainland Europe. The dry lined inner walls of Perpetual House were constructed with a gypsum plasterboard with a site applied skim joint prior to decoration.

## DISCUSSION

The facades of the two case study buildings are clearly very different and have different impacts on the environment. It is however extremely difficult to make comparisons, except on single quantifiable issues such as thermal performance or embodied energy. Even comparison of these issues is not straight forward.

The calculated 'U' values for Minster Court and Perpetual House are respectively 0.5 $W/m^2K$ and 0.227 $W/m^2K$. In the light of the questionnaire responses which showed that the industry currently rates reducing energy consumption of high importance for environmental impact, Perpetual House achieves a better rating. The designs however were undertaken at different times and both were well below the existing regulation requirements in force at the time.

The embodied energies of the two cladding systems have not been calculated but the transport elements of the Minster Court panels are clearly far greater than Perpetual House.

It is interesting to note that in cost terms the cladding of Minster Court represented approximately 18% of the total building cost and for Perpetual House it was approximately 12%. They were both therefore significant components of the building costs.

## CONCLUSION

The case studies have served to demonstrate that it is not possible to make clear design decisions based on 'environmental impact' because of the unquantifiable nature of many of the impacts and of the complex inter-relationships between the issues. They have however demonstrated the significance of the environmental impacts of construction materials and the need to consider these issues at the design stage.

The questionnaire has demonstrated that the current consideration of environmental impact by designers and manufacturers is the effect on the running of the building. Primarily considering the transmittance of natural daylight into the building and the control of heat flow into and out of the building and consequently the heating and cooling energy consumption of the building.

Although the environmental impacts of the building occur before and after the operation stage there will be a need for a great deal more information to be made available to the building designers and there is a call for financial incentives to assist the selection of sustainable solutions.


## Acknowledgements

Our grateful thanks are due to Prudential Portfolio Managers Ltd and to Perpetual PLC for their permission to undertake the case studies of their buildings.


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Fig. 1. Minster Court

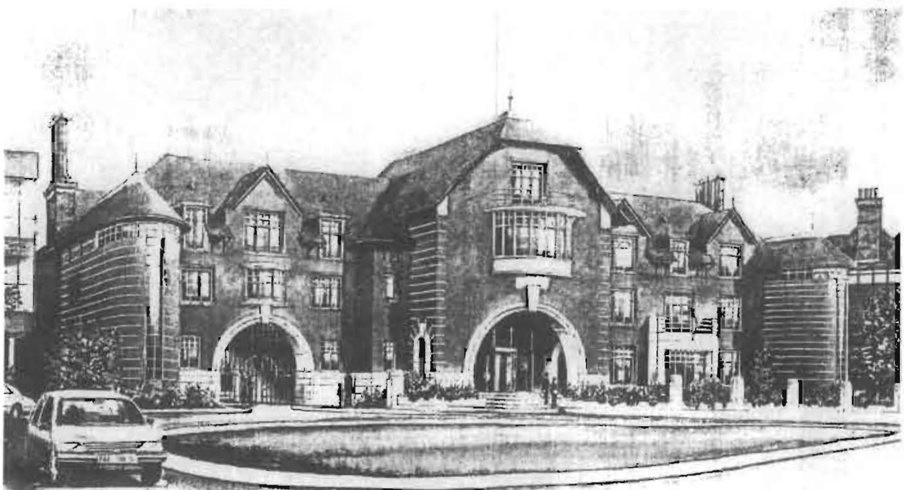

Fig. 2. Perpetual House