Hurst park housing design competition environmental design review

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ABSTRACT: This study expands on an environmental design report in partial fulfillment of the writers' M.Phil in environmental design in architecture. The scope of this study is to review how environmental issues enter into the creative process of an environmental design assignment. The assignment integrates within the design process physical and software tools. The study proposes that core environmental guidelines are generative in the design process and environmental tools function best as assessment, validation and fine-tuning of that process.

Conference theme: education/construction
Keywords: core environmental guidelines, design process, environmental tools

INTRODUCTION

The design assignment was a housing design competition set by the British construction company Wates Built Homes. As part of *Project House 2000*, the competition underlined the company's policy in offering a radical new range of housing for the future. The brief was to design a group of housing units in a suburban context (Hurst Park, Surrey, UK) accommodating 50 people. There were no specific restrictions regarding the typology, size or arrangement of the design. It was required, however, to respond to issues on energy and sustainability through a green agenda incorporating a set of guiding design principles.

GREEN AGENDA

SITE: Preservation of the natural environment. Protection and enhancement of distinctive features of the site such as grassland, trees, recreational facilities and play areas. Protection and enhancement of the existing ecosystems. Use of the existing infrastructure. Control of overshadowing and wind access.

ENERGY: Conservation and optimization of energy resources through specific design features. Use and control of renewable energy sources. Appropriate insulation strategies. Low embodied energy materials.

OTHER: Building adaptation such as incorporation of flexibility in building use over time. Promotion of health through air quality.

METHOD

This study reviews the environmental design process beginning by the site and climatic context. It then moves to consider the genesis of the plan layout and the architectural scheme. This is followed by a critical appraisal of the integration of sunlight, daylight, ventilation in the design development and its energy implications. The final design is presented with comments on the principles underlying the design choices. The study concludes with considerations on the integration of environmental issues in the design process.

1.0 SITE AND CLIMATE

East Mosley is a small suburb located 30km south west of London, UK. The competition site lies between the villa development along Hurst Road and the recent developments that occupy the river Thames front parallel to a private road (Fig.1). At the north-east the landscape opens into a greater green space (Hurst Park) reserved for future tree plantation. The quality of the natural and built environment is immediately perceived upon visiting the site, calling for preservation of the housing stock and conservation of its natural features.

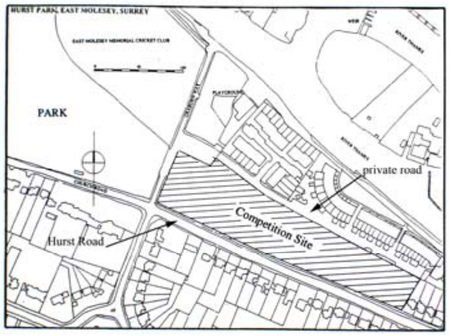

Figure 1: The competition's site.

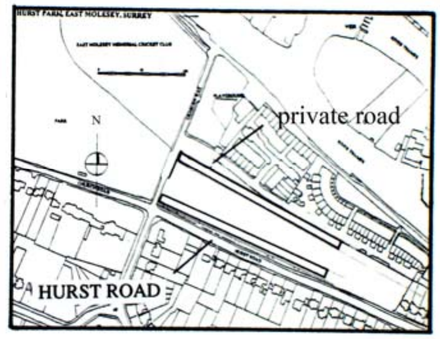

Figure 2: The two plan layout options.

CLIMATE

Climate data of the site were observed through the program METEONORM (METEONORM, 1977) considering as reference station Kew.

Temperature

Cold months: average external air temperature is for 11 months of the year below comfort levels, suggesting provision of adequate insulation systems and the harvesting of solar radiation through atria and sunspaces.
Hot months: average external temperatures do not normally exceed 19°C, a comfortable temperature. This avoids cooling loads but suggests ventilation techniques for atria and sunspaces.

Solar Radiation

The amount of useful solar radiation on the vertical plane of the building is strongly dependent on building orientation. The average total yearly solar radiation value for the SW orientation of the site is 767 KWh/m2. This represents 95% of the value for a full south exposure in that location, indicating that the orientation of the site lends itself to sunlight harvesting.

Wind

Prevailing winds have for 60% of the year a Westerly direction, primarily in the summer and winter months. In the design of a south-west orientated building façade, this tendency could constitute an advantage for reinforcing cross ventilation in the summer months.

2. DESIGN GENESIS

The design was approached at an urban and architectural scale. The two scales of design are presented as *plan layout* and *architectural scheme*.

2.1 Plan layout

The green agenda's guidelines indicated towards the preservation of the green spaces and infrastructure, the harvesting of solar radiation, the promotion of daylight and the utilization of wind patterns. The SW orientation of the site presented the opportunity for a favorable exposure to solar radiation and prevailing wind. By containing the building's footprint, a vast area of the green space could remain untouched. Furthermore, a shallow footprint would increase the potential of the building for daylight and ventilation.

I approached the design by conceiving a long and shallow SW orientated building, with the two options of locating the building either along Hurst road or the private road at the back of the site (Fig.2). The building opened to the SW exposure with a glass façade apt at collecting solar radiation.

This initial layout responded to the green agenda's site guidelines. Seen in retrospect, it generated a robust framework that allowed for the exploration of different architectural solutions throughout the design development, having as background the support of core environmental principles. The design process showed to be reversible meaning that, should an architectural scheme prove ineffective, it was always possible to return to the plan layout as reference.

2.2 Architectural scheme

The plan layout offered a building volume that was prone to harvesting solar energy, natural ventilation and daylight. At an architectural scale, the final aim was to generate a passive or low energy design scheme.

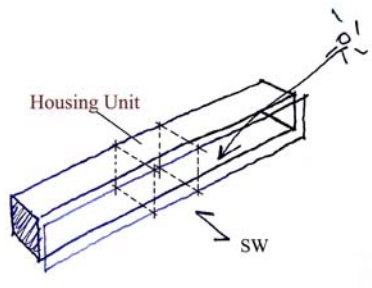

Figure 3: The building's volume in the plan layout.

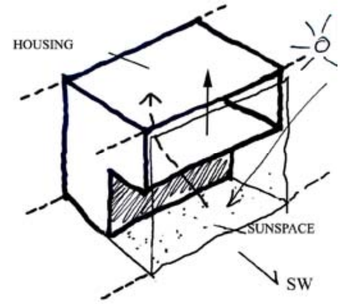

Figure 4: The housing unit: composed of housing and sun space.

By sectioning the building's volume (Fig.3) into housing units, the environmental advantages of the plan layout could be transported to each of the units. Moreover, the ground floor of each unit was recessed to create a sunspace (Fig.4). The idea was that the sunspace would provide heated air to the housing through natural buoyancy. In times when heating was not necessary, air movement inside the sunspace could be provided by creating an opportunity of ventilation to the outside. This was achieved by detaching the glazing from the housing and creating a stack chimney. The combination of housing, sunspace and stack chimney determined a system that could potentially control the temperature and airflow of the unit throughout the year. These assumptions, however, were entirely based on a qualitative approach to the design brief. Their implication on energy values was tested using the support of environmental tools, as shown below.

TESTING THE ARCHITECTURAL SCHEME

The architectural scheme was tested using the Atrium (Atrium, 1992) and Stack (STACK, 1996) spreadsheet programs. Typical to energy tools, the Atrium and Stack programs required specific input of the building's characteristics such as building geometry and building fabric for computation. Any change in the building's design required new input of data for a new computation. The building was therefore designed *prior* to controlling its environmental performance and the tools' function was to *assess* rather than *generate* the *design.*

A base case architectural scheme was tested with insulation *targets* based on environmental design principles and with insulation *values* based on recommended standards (Fig.5 and Table 1).

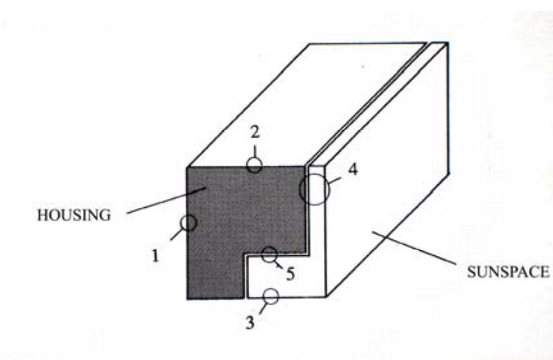

Figure 5: Insulation of housing units and sunspace.

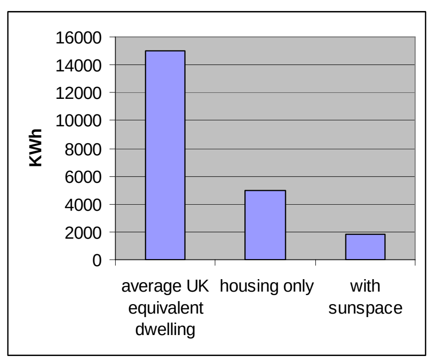

Figure 6: Total yearly energy loads.

Table 1: Insulation target of the base case architectural scheme

location	target	Layer description	U-value W/m2K
(1) N-E/N-W/S-E walls	superinsulation	Reinforced plaster (5mm); polystyrene – high density (150mm); brick (80mm)	0.20
(2) Roof	superinsulation	Reinforced plaster (5mm); polystyrene – high density (150mm); horizontal air space (100mm); aluminium cladding (2mm)	0.21
(3) Ground	Insulation from ground temperature and humidity. Stabilisation of sunspace temperature through thermal mass.	Brick tiles (20mm); concrete with expanded clay mesh (100mm); polystyrene – high density (150mm); reinforced concrete (120mm); gravel (80mm)	0.20
(4) S-W Wall	Insulation from the outside but thermal gains. Stabilisation of sunspace temperature.	Reinforced plaster (5mm); polystyrene – high density (80mm); concrete (100mm, with deck profile); internal rendering (5mm)	0.20
(5) Floor underside	Stabilisation of sunspace temperature	Timber flooring (20mm); polystyrene – high density (80mm); concrete (100mm, with deck profile); internal rendering (5mm)	0.35

Relative to an equivalent UK dwelling (Penz A.N., 1983), results indicated a highly energy efficient scheme and the significant contribution of the sunspace in reducing energy loads (Fig.6). It is important to note that variations to the base case architectural scheme such as sunspace configurations, materials' colours, glazing types and their location did not significantly vary the energy efficiency of the design, suggesting that the efficiency of the design was not coincidental. The environmental tools helped to monitor the energy implications of the different design options and to select, from the many possible, the most appropriate for the task set. It could be argued that an appropriately set scheme, with environmental guidelines applied at the onset of the design process, by itself directs the design towards an energy efficient solution.

3. DESIGN DEVELOPMENT

The green agenda's guidelines and the subsequent plan layout helped to develop an architectural scheme that responded to fundamental environmental issues. Furthermore, the energy efficiency of the architectural scheme was tested and confirmed through the support of the Atrium and Stack spreadsheet programs. In order for the design to develop into an environmentally sound architecture, however, it also had to provide evidence of proper sunlight, daylight, and ventilation features. These features were integrated, tested and refined in the design development shown below.

3.1 Sunlight control

Sunlight control was seen from two perspectives: in the plan layout to prevent overshadowing; in the architectural scheme to promote solar heat gains in the cold months and prevent solar heat gains in the hot months. The design development used the Heliodon and the P.E.M. program (P.E.M., 1995) to study solar geometry, and the Atrium program to quantify the implications on energy demand.

3.1.1 Plan layout and overshadowing

Of the two options shown in Fig.2, the development along Hurst Road was preferred because it best utilised the existing infrastructure. There were concerns, however, that the location and orientation of the development might overshadow the green area of the site, particularly during the cold season. To verify this, a model of the building was tested using the Heliodon for the cardinal periods of the year. It was shown that for the periods between the Equinoxes to the Winter Solstice, a continuous opaque building along Hurst road would overshadow the green area in the afternoon hours, contributing to outdoor thermal discomfort in the cold months (Fig.7).

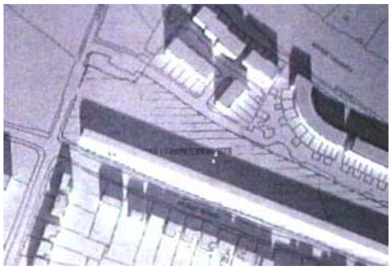

Figure 7: Overshadowing of the green area in the Hurst Park option.

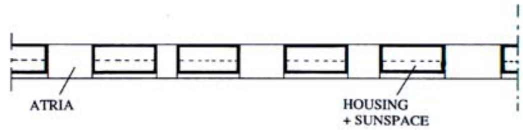

Figure 8: The permeable scheme solution with free arrangement of the units along the SW façade.

A compromise could be reached through a *permeable* scheme, composed of building units and atria spaces (Fig.8). This would allow the building to remain in the same location and the green areas to be partially sunlit. Two aspects of the solution, however, needed to be evaluated. First, the degree of contribution of the atria to passive solar gain. Second, the degree of sunlight patches reaching the green area.

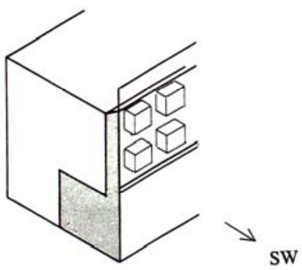

Figure 9: Insulating the non-solar partition.

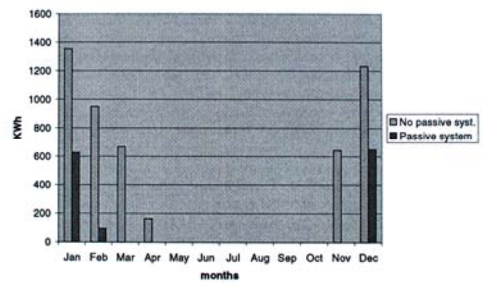

Figure 10: Average monthly heating loads with and without the sunspace's insulated non-solar partition.

The first aspect was tested using the Atrium program. In this instance, it was shown that the atria spaces would reduce the total yearly energy loads of each unit by approx. 25%, depending on their size. Further testing, however, also showed that this increase could be minimized by simply replacing the non-solar collecting partitions of the sunspace with an appropriately insulated material (Fig.9 and Fig.10). In energy terms, the confirmation of this easily achievable result liberated the SW glass façade from the housing units, encouraging a flexible disposition of the housing units along the façade. The second aspect was tested using the Heliodon and was directly related to the energy results discussed above. In this instance, depending on the arrangement of the housing units along the glass façade, the Heliodon tests indicated that a high degree of control over the sunlight patches could be achieved for the hours of interest. In both aspects, testing allowed for control and revision of the basic plan layout.

3.1.2 Architectural scheme and solar energy

In general terms, solar energy is desirable in the under-heated periods of the year while undesirable in the overheated periods of the year (Olgay and Olgay, 1957). The choice of materials, and the consequent solar gain factor, is particularly significant in greenhouse spaces. For clarity, the implication of solar energy in the housing and the sunspace is considered separately.

HOUSING By *by-passing* the sunspace through the window reveal (Fig.15), I generated a shading device that protected from the penetration of summer sun and created a potentially effective ventilation system (described in section 3.3). The exact depth of the window reveal to control solar geometry was calculated using the P.E.M. program.

SUNSPACE The design concept envisaged the sunspace to be habitable. A contribution in containing sunspace heat-up and reducing glare was proposed through the design of moveable shades, while the control of the solar gain factor through the selection of different materials determining the mean room reflectance inside the sunspace (Fig.11).

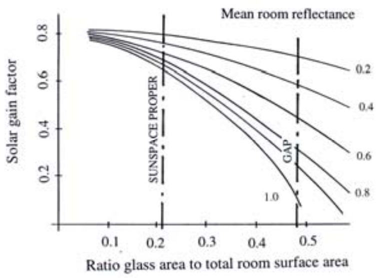

Figure 11: Solar gain factor in the two parts of the sunspace

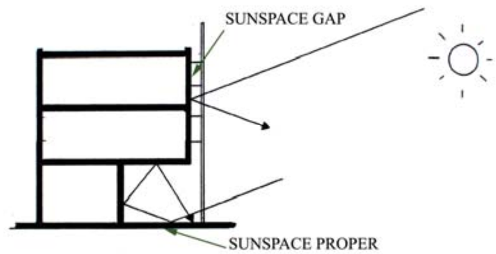

Figure 12: Sunspace and solar heat gain

The energy implications of this design approach were verified using the Atrium program. Results showed the effectiveness of the moveable shades to control overheating and that the solar heat gain depended on the reflectance and location of the materials, less critical in the sunspace proper and more critical in the sunspace gap (Fig.12). The environmental tools helped to give a value, to ascertain the importance of solar control on heat energy reaching the building. They also helped to define the implications of specific cladding materials on solar energy and to reach a solution that was both inspired and informed.

3.2 Daylight

Daylight was tested for the architectural scheme using a physical model and artificial sky. Reading points were set in a mesh of approximately 1 meter with a reference height of 900mm –corresponding to the working plane. The main objective of the analysis was to examine the average DF and the DF distribution for a typical housing unit floor with evenly placed windows. The target was to develop a design that complied with the daylight standards set by CISBE (CISBE, 1987) and the Lynes critical ratio shown below (Lynes, J.A., 1968):

K = aver. DF front half of the room/aver. DF back half of the room
Where: if K is greater than 3, the room will appear as unacceptably gloomy.

Testing confirmed satisfactory average DF values for each specific room use. Daylight *distribution*, however, needed improvement. It was shown that this could be achieved by simple adjustments on window locations, such as the alignment of one of the windows with the living room axis (Fig. 13 and Fig.14).

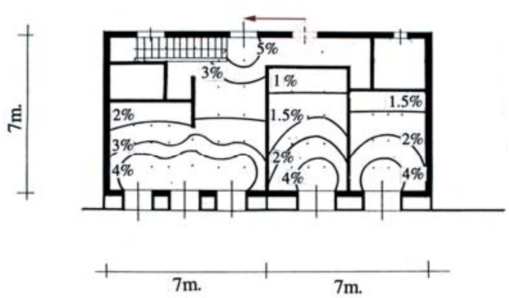

Figure 13: Adjusting window location.

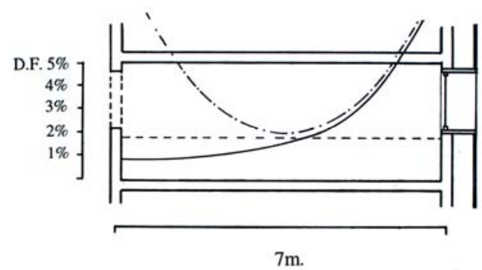

Figure 14: Improvement of daylight distribution with new window location.

As mentioned in section 2.2, a shallow building, with a window height to room depth ratio not greater than 1: 2.5, has in general terms a high potential for receiving daylight. This basic rule-of-thumb guideline has shown to provide satisfactory average DF values and to require modifications only in terms of fine-tuning of daylight distribution, a qualitative aspect of daylight.

3.3 Ventilation strategy

The goal of the ventilation strategy was to design a building that would promote thermal comfort and guarantee air quality.

Due to its direct solar gains, ventilation control of the sunspace was critical both in the cold winter months and in the hot summer months. As mentioned in section 2.2, an approach to controlling ventilation was to create a chimney effect by detaching the glazed facade from the housing units and creating a system that could improve thermal comfort in the sunspace and housing unit (Fig.15).

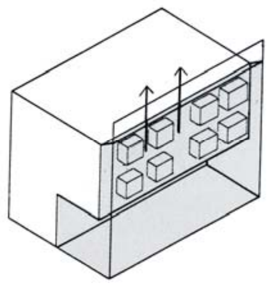

Figure 15: Window reveals and bypass.

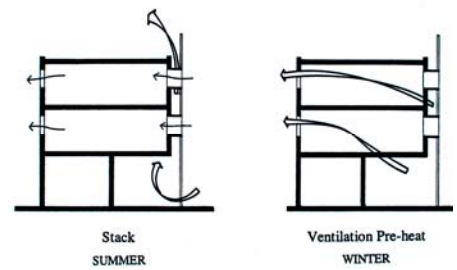

Figure 16: Winter and summer ventilation system.

The combination stack chimney and window reveals created a *by-pass* system that allowed for two ventilation modes. In summer, the chimney would ventilate the sunspace and the window openings cross ventilate the housing units. In winter, the sunspace would work as a preheating device to the housing units (Fig.16). The implications of these design concepts on the number of air changes and temperature increments in the sunspace was studied using the Stack and Atrium spreadsheet programs, considering two ventilation extremes:

0.5AC/h as minimum ventilation rate to guarantee air quality but avoid heat loss

10 AC/h maximum ventilation rate to induce cooling but avoid air movement disturbance.

Several computer applications on the chimney aperture area indicated a very efficient stack system, requiring less than 0,3 m2 to achieve a ventilation rate of 10 (AC/h) and a temperature drop of 8°C as shown in (Fig.18). This promoted the incorporation of casement windows of variable opening area and thus variable ventilation and temperature values in the sunspace (Fig. 19).

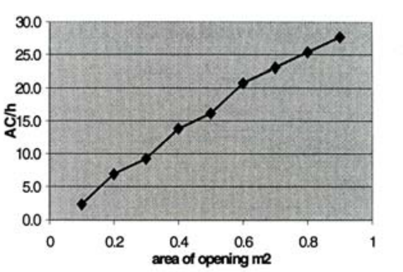

Figure 17: Aperture area and AC/h.

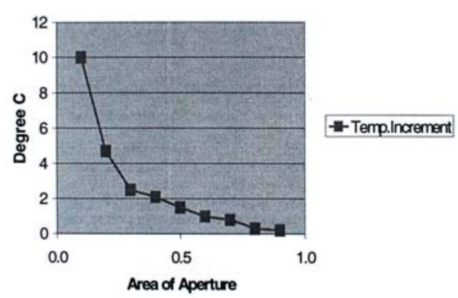

Figure 18: Aperture area and temperature increment.

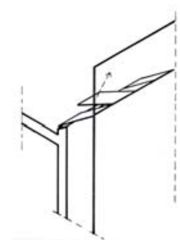

Figure 19: Incorporation of casement windows.

Results showed that, for 0.5 AC/h, the sunspace temperature would be below comfort levels in December and January, thus requiring heating loads in those months. In the summer months, 10 AC/ h would generate some overheating, which nevertheless remained at acceptable levels. It was concluded that the sunspace would require some heating loads only in the critical cold months (December and January) and did not need particular alteration to its design scheme. In the summer months, further improvement in cooling could be obtained through sunspace shading.

4. FINAL DESIGN PROPOSAL

The final proposal foresees the use of housing units freely arranged along the SW glass façade (Fig.20). For compactness, each unit comprises two apartments in three levels. The SW glass facade operates as a *plug-on* passive system: when the housing units plug onto the façade this creates a sunspace that generates solar energy. The atria space between the units has no energy function, its primary role is to allow for sunlight to reach the green areas and as sheltered vertical space between the apartments. The primary structure of the entire building is composed of slim steel frames set at 7.0 m apart. These contain within their depth a profiled steel floor decking. Steel is used as main material for its moderate embodied energy (EE 11.15KWh p/kg), speed of erection and precision in assembly. The envelope is primarily composed of brick veneer, with the base case insulation targets and recommendations set by Table 1. To maximize solar heat, the SW façade of the housing should be of dark color finishing. In this instance, however, energy performance was superseded by the aesthetics beauty of exposed red brick veneer, an example of striking a balance between quantitative and qualitative values. More freedom is left to the treatment of surfaces inside the sunspace proper where color choice has shown to be less critical for solar heat gain. The SW façade of the housing is characterized by a stack chimney and window reveals that generate a bypass system that engages or disengages the thermal contribution of the sunspace to the housing. The reveals also act as solar control devices and as light shelves for daylight penetration.

The environmental tools confirmed that the final design proposal is highly energy efficient, that its geometry responds to sunlight and natural ventilation and that each of the living areas are properly day lit. The proposal, however, remains highly schematic. It is in fact a strongly conceptual *environmental scheme* that nevertheless allows space for further architectural development and expression.

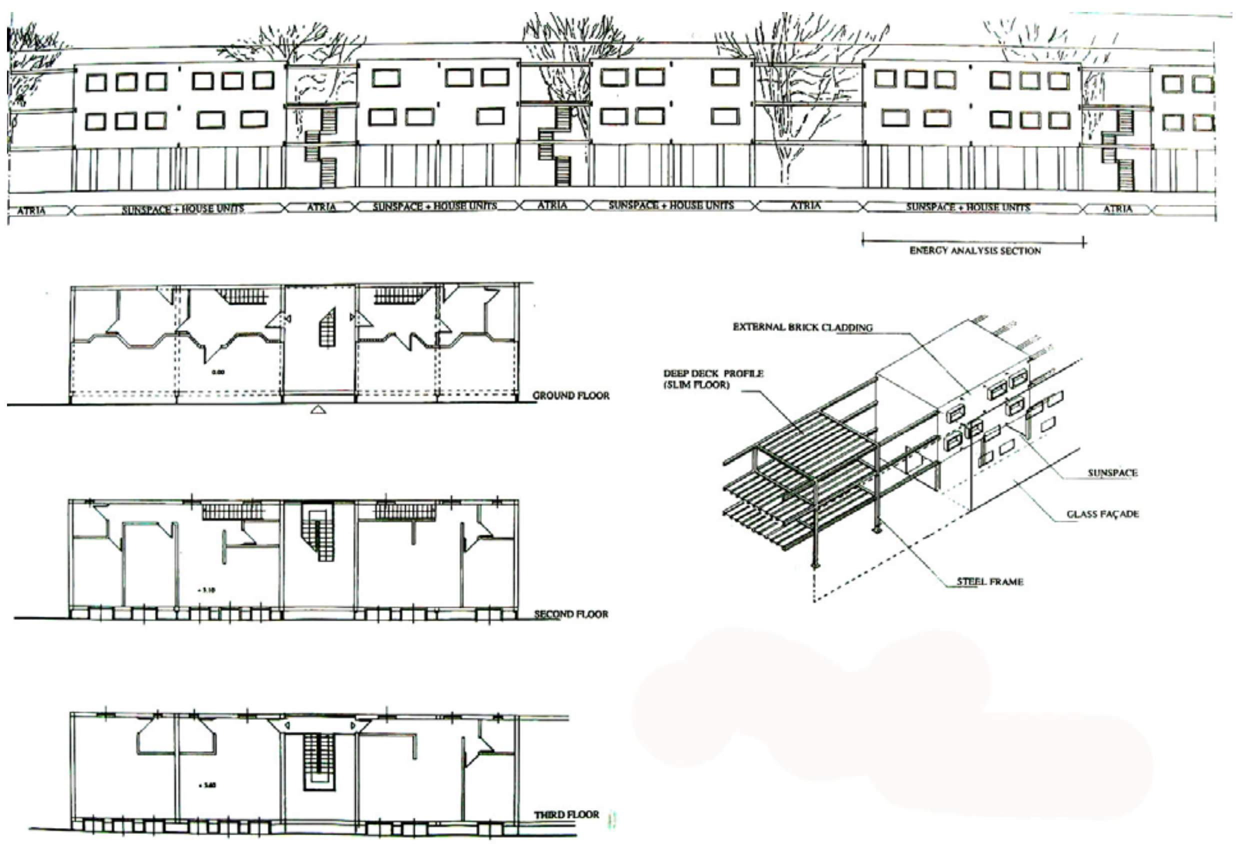

Figure 20: The final design proposal.

CONCLUSION

The environmental design assignment has allowed to test in first person the implications of integrating environmental issues in a design project. The review of the design process has brought the attention to the following points:

- The incorporation of the green agenda's guidelines at the onset of the design process creates a framework that works as secure environmental reference for the development of a design's scheme.

- Quantitative results suggest that a base case design that responds to key environmental guidelines through qualitative environmental design considerations by itself directs the development of that design towards energy efficiency.

- The integration of core environmental principles is generative in the design process. Because environmental tools require the input of established design data, they show to be more effective for validating and monitoring the design process. It could be argued that the constant use of the environmental tools in conjunction with the design process will help the designer develop an intuition on the quantitative implications of their design choices.

The nature of the assignment, a design competition, suggests that the above study concerns both an educational and professional audience. In this direction, the findings of this study suggest that the application of simple concepts and basic formulas could help the student and the professional to find an accelerated, intuitive connection between the qualitative and quantitative values of a design that incorporates environmental issues.

ACKNOWLEDGMENTS

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