ECONOMICAL ENERGY EFFICIENT LARGE SCALE OFFICE BUILDINGS

W A Birrer
Visiting lecturer, Sydney University of Technology
fax: 61 2 4324 6106

ABSTRACT *The objective of this paper is to show that:-*

1 *Passive energy conservation strategies combined with active (mechanical) systems can be successfully applied to large office buildings*

2 *In a temperate climate this can be done for the same cost - or less - than the cost of a conventional air conditioned office building of similar size.*

3 *The technical, environmental and user friendly benefits resulting from the above exceed those of conventional office buildings.*

To fully describe the implications of the above, resulting from over 25 years of personal research and construction experience would require a publication substantially beyond the limits set for this paper. It must suffice therefore to simply outline methods and results from examples constructed and occupied over the past 20 years, in this case, the three buildings of the 180 000 m^2 Standard Bank Centre in Johannesburg, South Africa. shown in Fig.1. The success of the first 54 000 m^2 building, designed in 1978 and occupied in 1982 was followed by a second building of 96 000m^2, completed in 1986. A third building of 30 000m^2 was completed in 1996. The design concept, technical and energy conservation strategies of the first building were carried through to the last building, although details were simplified and refined along the way as a result of use and experience.

Fig.1 The Standard Bank Centre showing buildings 1, 2 & 3

1 Process and realization

1.1 The brief

No responsible architect should commence design without a comprehensive Brief. It details the owner's requirements, establishes performance criteria and is the document against which the completed building will be measured when the architect carries out the post occupancy evaluation for the owner. For the first Standard Bank Building in 1978, the Brief document comprised two full A4 lever-arch files and was prepared by the project team consisting of the professional team and Standard Bank representatives under the direction of a renown office planner from Zurich. From the beginning, the project was blessed by the personal interest and visionary foresight of the Managing Director who supported the unconventional design that emerged.

Apart from the many detail requirements, three major directives arose from the brief:

1. A low rise compact building with deep, flexible open office space to accommodate large divisions on one floor (The open office throughout - later extending to executives' "offices" - broke the old culture of isolationism with individuals ensconced in cellular accommodation. Subsequently there emerged a vibrant organisation with enhanced internal identity and interaction at all levels)
2. An energy efficient building to reduce initial and subsequent operating and maintenance costs.
3. Capital cost not to exceed that for a traditional building of equal area.

1.2 Design process

An integrated design team working in close collaboration was chaired by the architect. The conventional hierarchical linear design procedure where one profession's solution becomes the other's problem with drawings passing to and fro until a mutually acceptable solution is achieved, was rejected in favour of cooperative team design. It focused all the team's collective intellect on a problem at one time. It was an effective use of human resources and was in the owner's best interest, achieving mutually acceptable solutions more quickly, as indicated in Fig.2. It meant that the architect was not the sole design arbiter; everyone had equal say and contributed constructively, the design quickly emerging from analysis, logic, reasoning and value judgment decisions, based on criteria contained in the brief.

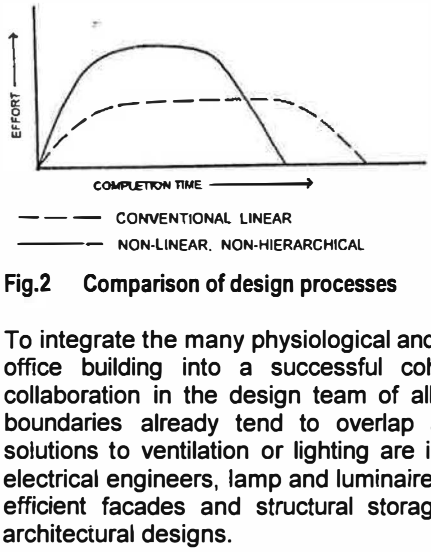

Fig.2 Comparison of design processes

To integrate the many physiological and technical requirements of today's highly engineered office building into a successful cohesive whole requires the close and continuous collaboration in the design team of all disciplines, especially since hereditary disciplinary boundaries already tend to overlap and become blurred. Successful and economical solutions to ventilation or lighting are influenced by the technical input of mechanical and electrical engineers, lamp and luminaire manufacturers. Similarly, requirements for thermally efficient facades and structural storage influence the structural, ventilation, lighting and architectural designs.

From the outset, the architect's design can be the greatest contributor towards saving energy as Fig.3 - prepared by an engineer - indicates. It shows a possible reduction of up to 40 W/m² (over 30%) in the cooling load and a little over 20 W/m² in the heating load, bearing in mind that in office buildings cooling is usually the bigger issue.

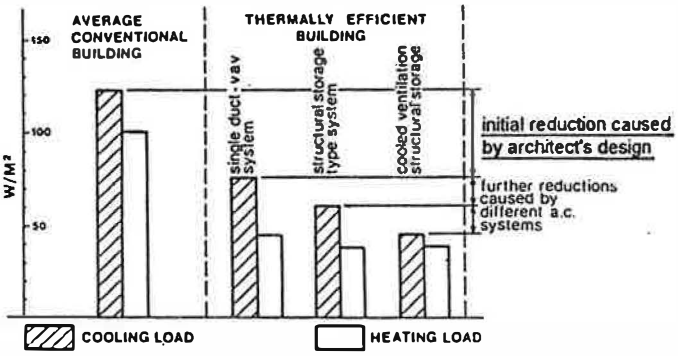

Fig.3 Possible reduction of 30-40% in energy requirements, plant size & cost, by architectural design

To satisfy the brief's first directive and to adequately service workstations (W/S) in the deep space, a raised access floor emerged as the best way to provide sufficient space and flexibility for distributing power, data and voice cables in anticipation of Information Technology requirements, an unknown quantity in South Africa in 1978.

With no services under the slab, the need for a suspended ceiling disappeared and the concrete slab was exposed and available for thermal storage to act as a passive temperature moderator, enhancing the building's energy efficiency and reducing plant costs.

As design progressed, it became apparent that others had to be brought in if at the end everything was to be assembled satisfactorily . Manufacturers of luminaires, office furniture and the raised access floor to name a few, joined the design team to ensure the successful interface of W/S with uplights, power, data and voice connections resulting in a host of manufacturers' prototypes and mock-ups. This early cooperation was rewarded later, when everything came together smoothly and easily.

Diehards' reaction that such an arrangement either is not done here, impossible, won't work here, etc. simply shows a lack of will, initiative and a resistance to change.

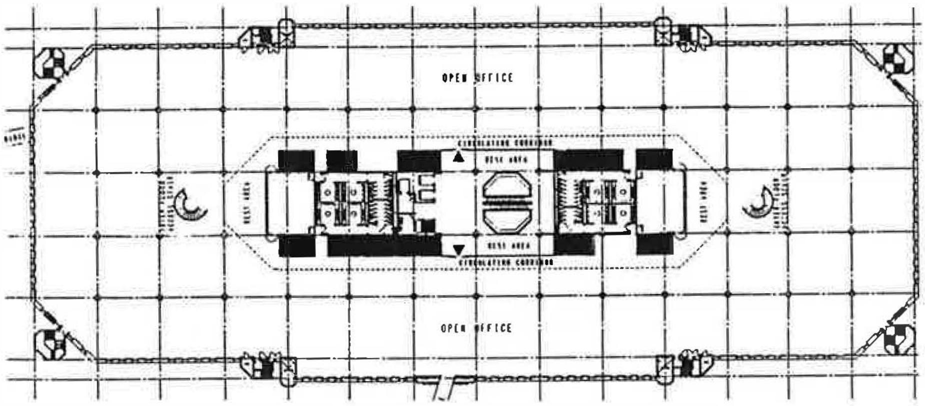

Fig.4 Typical office floors 1 – 4

1.3 The design

Today, sophisticated computer software is readily available to assist design, to predict performance and to reassure the hesitant building owner. Twenty years ago reliance was based on logic and empirical data which, happily, produced the expected results.

The building's form was influenced by the size and shape of the site giving rise to a plan approximately 165 m x 65 m wide (Fig.4), with four typical open office floors and further office space on ground and sub-ground floors. Also on ground floor is a cafeteria to serve 2500 and an auditorium. On the roof are a gymnasium, squash courts and saunas.

Measures taken to conserve energy in the architectural design included:-

1. Creating a heavy thermally efficient building and envelope i.e., U values for roof and facade not exceeding 0.75 W/m^2K and 1.25 W/m^2K respectively This reduced internal temperature swings and energy requirements compared with conventional thermally inefficient design as Fig.5 illustrates.

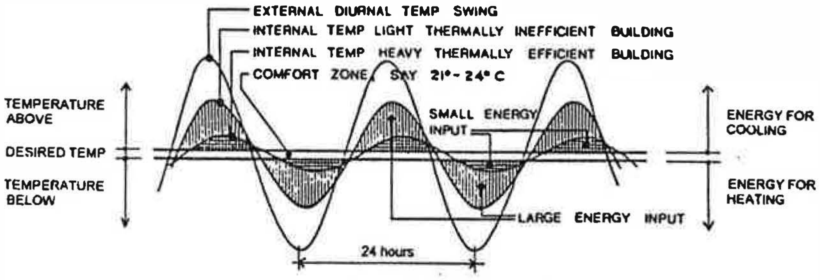

Fig.5 Difference in energy requirements between a heavy thermally efficient building and a light thermally inefficient building

2. Placing escape stairs with natural light and ventilation on the periphery thus eliminating the need for pressurisation and electric lighting by day and incidentally, in the event of a crisis, dispersing people outwards rather than congesting them inwards at a few internal staircases.

3. By utilising structural heat storage and night cooling, exposing the concrete slab to act as a heat sink, to absorb heat generated during the day by people, equipment and lighting then flushing with cool night air, thus reducing the cooling load, plant size (and cost), Fig.6.

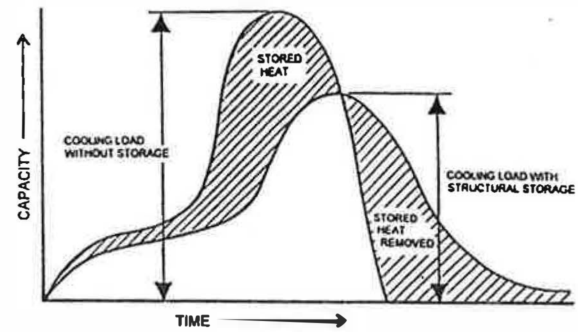

Fig.6 Effect of structural storage on cooling load

4. Installation of a low pressure underfloor system with a reduced capacity, because of items 1, 2 and 3 above. With individually controlled fan air terminals (FATs) at W/Ss the system's aims were to provide comfort for individuals and not climates for areas and to reduce maximum demand.

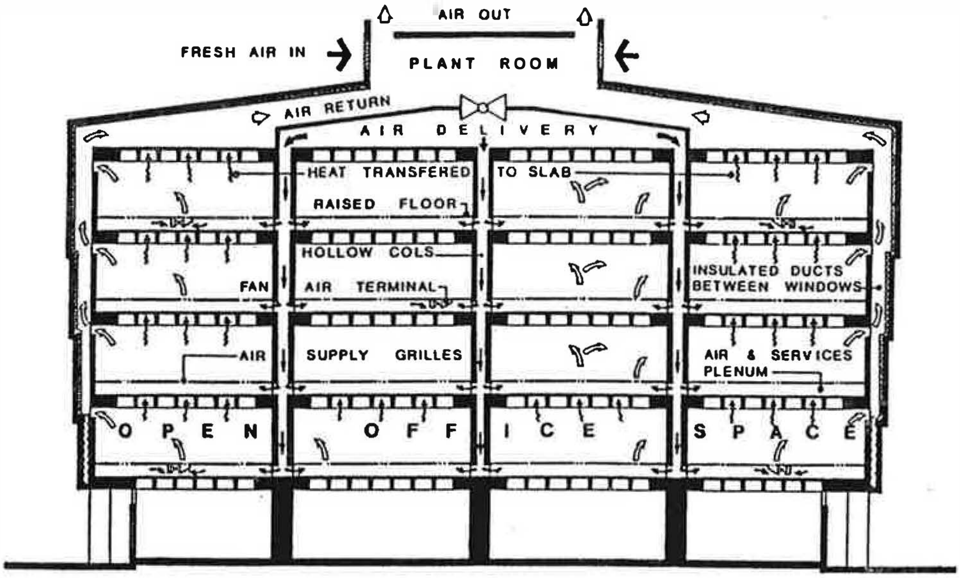

Fig.7 Schematic section through building

Fig.7 shows how the above were integrated into a total building design. Air is passed down the columns distributed into the air and services plenum beneath the raised access floor, emerging to rise up towards the concrete in a natural way as it warms and is then extracted below the concrete ceiling into insulated precast concrete ducts between the windows, giving the facade its architectural character It is a 100% once through, clean air system.

With deep space lighting was a prime consideration. After exhaustive reviews of alternatives and research abroad, individually controlled W/S-located uplights were selected, a decision never regretted. With no commercial uplights being then available, locally made luminaires with 250 W metal halide lamps were installed, compact fluorescent lamps having not yet appeared.

In 1998 after 16 years of occupation the building was renovated, services upgraded, and a local area network system installed by simply lifting floor panels The uplights were replaced with more efficient luminaires with compact fluorescent lamps now available, due to market demand (Fig.8) and installed in the last building completed in 1996. Within easy reach are the controls for fan air terminals, temperature and light, including the ability to control the illumination level to suit individual visual comfort. Occupant surveys showed that this could vary by up to 200 lux,

3 Results

3.1 Cost

3.1.1 Construction or capital cost This was controlled through Bills of Quantities and competitive tendering. It showed that the unit cost was no more than that for conventional buildings in Standard Bank's extensive property portfolio. Major factors confining capital cost were due mainly to a 40% saving in plant cost, omission of suspended ceilings, sheet metal air conditioning ducting, hire and erection of scaffolding for overhead

Fig.8 Typical W/S and uplighter in building 3 with control unit (inset). Note latest circular FAT grille, extreme left

services installation (now laid on the floor). These paid for the raised access floor, double glazing and insulation. In addition, the plug-in uplight luminaires were a direct purchase, eliminating contractor's fee for taking delivery and handling. Moreover, now classed as furniture, they were depreciated at a similar same rate

3.1 2 Energy (operating) cost (Johannesburg's main source of energy is electricity) Energy costs were up to 40% less than buildings of similar area. In its first year the electricity bill for this building was R 750 000 less than that for Standard Bank's existing 28 storey HQ building, although the new building was 50% larger and had a far higher density of computer and related equipment, plus it had to support a large cafeteria, the gymnasium, saunas, squash courts and ablution facilities.

3.2 Performance

With longer working hours - even continuous 24 hour operations - becoming more common, comparing one building's performance with another is no longer straight forward. However, at 2500 operating hours per annum, the potential performance of the three buildings is given in Table 1

Table 1 The potential performance of the three buildings of Standard Bank Centre

Building	*Office* space m^2	kWh/m^2 p.a.	kVA/m^2
First	54,000	125*	30
Second	96,000	112	45
Third	30,000	138+	55

*Includes demands of cafeteria, kitchen, gymnasium and saunas
+Includes an international Dealers' Trading floor operating 24 hours

By comparison, for a conventionally designed and air conditioned office building in South Africa the average consumption is 247 kWh/m^2 p a and maximum demand is 78kVA.

3.3 Fexibility

20 years of occupation and with nearly 50% 'churn rate', has proved the space's flexibility with its simple under floor plug-in plug-out services (Fig.9) for W/Ss', FATs, data, electrical and voice connections, easily performed by in-house maintenance staff. It is quick and economical, avoiding external services, their costs and delays.

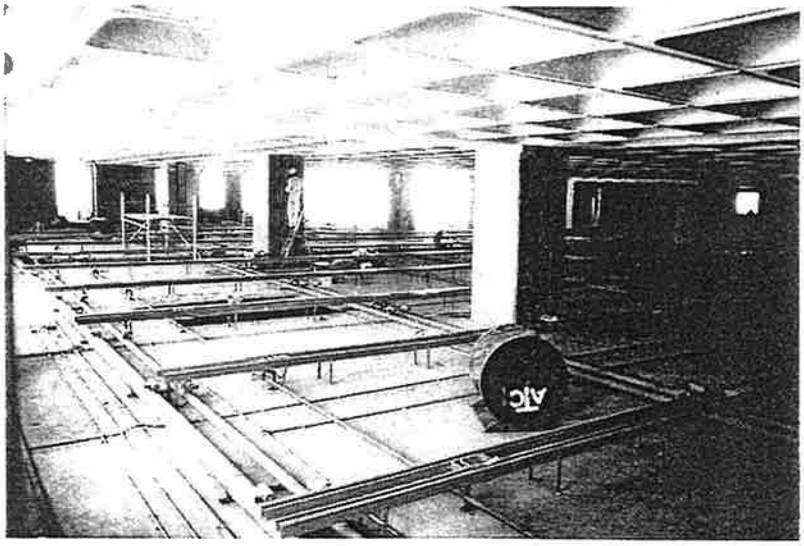

Fig.9 Services layout before installation of the raised access floor

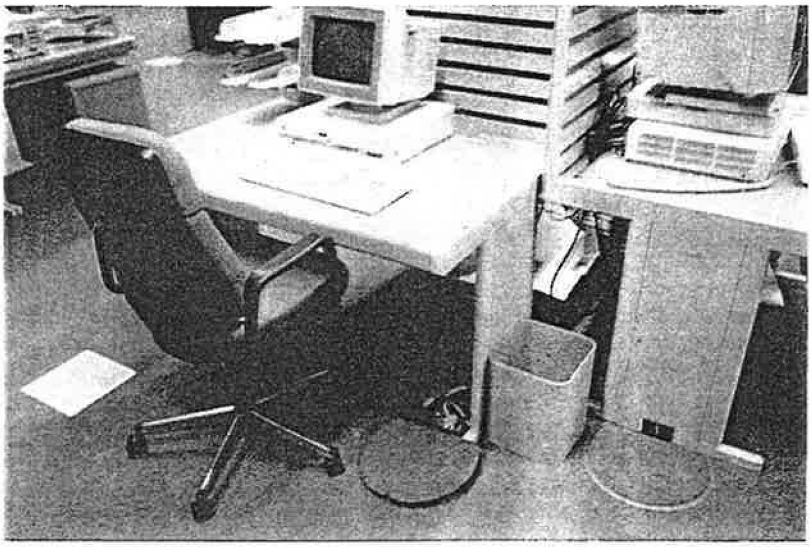

Fig.10 W/Ss anchored in position with access cover lifted. Square FAT grille, left of chair.

Fig.10 shows a typical W/S in the second building, anchored in position with a portion of the circular cover removed, revealing the multi-socket service module beneath, into which cables are plugged They are then concealed in the W/S's leg and carried up to the W/S's power board into which W/S occupants simply plug their equipment and switch on. In this way the potentially dangerous situation of wires and cables lying about on the floor, around W/Ss and under the feet of occupants is avoided.

3.4 Summary of benefits

3.4.1 Costs

- Unit construction costs not more than for conventional building
- Operating cost 30-40% less than for conventional space. In 1993 the second building won the prestigious Eskom Effective Energy Award. The Standard Bank Center News later stated that the first two buildings (a third under construction), had saved the Bank R 2 100 000 in power costs, a 37% saving on what the cost would have been had they been conventionally designed and air-conditioned buildings.

3.4 2 Flexibility

- W/S or Dept. layouts easily and quickly rearranged with in-house staff avoiding delays, external services and their costs

3.4.3 **More efficient and user-friendly space** because -

- The microclimate around the W/S can be personally tuned to suit individual comfort requirements of temperature, ventilation and illumination levels.
- No reflective glare or shadow because of uplighting.
- Quality and intensity of illumination always the same irrespective of the W/S's position.
- Overnight buildup of odours and volatile organic compounds (VOCs) flushed clear by night ventilation thus reducing possibility of sick building syndrome complaints.
- Comfort, morale and productivity potentially improved due to the above.

4 Conclusion

The post occupancy evaluations and occupant response surveys that were carried out showed a high degree of satisfaction among staff with the conditions in which they worked Since the first building Standard Bank has grown to become South Africa's foremost bank with Standard Bank Centre accommodating over 6000 employees

While the nature of office space and building briefly described here has, over the years, proved very satisfactory and met the needs of the Standard Bank, it is not suggested as a general panacea. In addition, with the subsequent appearance of laptops, mobile phones, broadband wireless for mobile connectivity permitting computing to take place almost anywhere at any time, the scenario outlined here may require modification.

However, a recent letter from the Property Maintenance Manager expressing pleasure with the renovation of the first building where, among other use changes, one total floor has now become a 24 hour call centre, states; "....thank goodness the buildings were designed in such a manner that they are fully flexible, otherwise they would long have been obsolete "

It may be of interest to note that in 1970 Standard Bank moved into a 28 storey structure specifically designed as a prestigious head office building. 15 years later, because it simply could not meet the demands of a dynamic organisation and of Information Technology, it was vacated and the top floor of the second building was converted into an executive floor with top management accommodated in open "offices". Because of the design, the floor was easily adapted to provide board and conference rooms, executive toilets, dining rooms, kitchen, cold rooms and kitchen staff change rooms and ablution facilities with all attendant plumbing, without disturbing the office floor below.

laws that he based his greatest work, the Parc Guell, the chapel of Santa Coloma and his latest models for the Sagrada Familia. In these works, the sculptural forms of that Mediterranean tradition of clear skies and bright sunlight that he had admired throughout his life came out of his own hands, not as another revival but as a new creation of the moment.

"The Catalans have a natural sense of plasticity that gives them an idea of the objects as wholes and also of the relationship of objects to one another. The sea and the light of the Mediterranean countries give this admirable clarity, and because of this, real objects do not mislead Mediterranean peoples, but instruct them."[xiv]

Gaudi was an individual well ahead of his times. His Belief was "form does not necessarily have to follow function, though it should not be in conflict with it."[xv] Function has an increasing variety of forms to choose from and this perhaps, is part of the legacy Gaudi has left us with.

Gaudi's unique combined method of thinking and seeing is perhaps his most interesting contribution to the world of architecture, and in this, he is even today, an Alternative Architect.

Fig. 8 Looking at the Sagrada Familia church.

3 References

Carson, Rachel. (1984): *The Sense of Wonder*. New York, NY. Harper.
Collins, George R. (1960): *Antonio Gaudi*. New York, NY. George Braziller, Inc.
Frampton, Kenneth. (1992): *Modern Architecture : A Critical History*. London, UK. Thames and Hudson Ltd.
Maragall, Joan. (1905): *A la Sagrada Familia (Obres Completes de Joan Maragall)*. Barcelona, Spain.
Orr, D W. (1994): *Earth in mind : on education, environment and the human prospect*. Washington, Island Press.
Permanyer, Lluis. (1996): *Gaudi of Barcelona*. New York, NY. Rizzoli International Publications, Inc.
Perucho, Juan. (1971): *Gaudi : An Architecture of Anticipation*. New York, NY. Tudor Publishing Company.
Pujols, Francesc. (1927): *La Visio Artistics i Religiosa d'en Gaudi*. Barcelona, Spain. Llibreria Catalonia.
Rafols, Jose F. (1928): *Gaudi*. ed. Canosa. Barcelona, Spain. 1928.

---

[i] Perucho, Joan. Gaudi : An Architecture of Anticipation. New York, NY. Tudor Publishing Company. 1971.
[ii] Collins, George R. Antonio Gaudi. New York, NY. George Braziller, Inc. 1960.
[iii] Maragall, Joan. A la Sagrada Familia (Obres Completes de Joan Maragall). Barcelona, Spain. 1905.
[iv] Tarrago, Salvador. Gaudi. Barcelona, Spain. Editorial Escudo De Oro, S.A. 1985.
[v] Gaudi, as quoted in Rafols, 1928. Rafols, Jose F. Gaudi (Barcelona : ed. Canosa). Barcelona, Spain. 1928.
[vi] Sweeney, James J. and Sert, Josep Lluis. Antonio Gaudi. New York, NY. Frederick A. Praeger, Inc. 1960.
[vii] Sweeney, *op. cit.*
[viii] Gaudi, as quoted in Sweeney. *Ibid.*
[ix] Collins, *op. Cit.*
[x] *Ibid.*
[xi] Orr, David W. Earth in Mind : On Education, Environment and the Human Prospect. Washington, DC. Island Press. 1994.
[xii] Orr, *op. Cit.*
[xiii] Gaudi, as quoted by Perucho, 1971. Perucho, *op. cit.*
[xiv] Gaudi, as quoted in Rafols, 1928. Rafols, Jose F. Gaudi (Barcelona : ed. Canosa). Barcelona, Spain. 1928.
[xv] Sweeney, *op. cit.*