

Bioclimatic Skyscraper – Learning from Bawa

Assistant Professor Dr. Tan Beng Kiang and Professor David Robson

Department of Architecture, School of Design and Environment, National University of Singapore
Email: akitanbk@nus.edu.sg

ABSTRACT: This paper describes what is regarded as having been one of the earliest bioclimatic office buildings designed for natural lighting and ventilation and draws lessons for present practice. The 12-storey State Mortgage Bank Building (now known as Mahaweli Building) in Colombo, Sri Lanka, designed by the late Asian architect Geoffrey Bawa in 1972, incorporated many environmentally responsive design principles long before the buzz words of bioclimatic and sustainable architecture became commonplace. The paper describes the background and context the project was designed for and its design principles and passive energy efficient strategies. It also discusses whether these principles and strategies are still applicable for designing bioclimatic tall office buildings in our time. The authors have interviewed members of the original design team, have collected material from the Bawa archives, have surveyed the current condition and use patterns of the building, have interviewed building users and have constructed a 3D computer model of the building.

Keywords: case study, bioclimatic, environmentally responsive, design strategies

1. INTRODUCTION

Geoffrey Bawa (1919- 2003), Sri Lankan architect and Aga Khan award winner, is best known for his tropical and environmental responsive hotels and low-rise buildings. However, during the 1970s, he moved away from designing private houses and hotels and focused for a while on the problem of the tropical urban workplace. Few knew of his office designs until they were featured in the Complete Works of Bawa [1]. They included the Steel Corporation Offices, Oruwela (1968), offices in Matara (1969), the Agrarian Research and Training Institute (1974), and the Institute of Management Studies (1975). All these buildings were low-rise and explored the principles for the design of naturally ventilated offices. They were followed by the State Mortgage Bank which was the only Bawa-designed high-rise actually to be built.

Bawa was commissioned to design the 12-storey State Mortgage Bank building (now known as Mahaweli Building) in the heart of Colombo, Sri Lanka, by the government in 1972, but midway through the project there was a change of government that resulted in it being re-designated as the headquarters of the Mahaweli Ministry and a delay in completion of the construction to 1978. Ken Yeang observed that Mahaweli Building 'is probably the best example of a bioclimatically responsive tall building to be found anywhere in the world' [2] and Robson commented that 'this design offered a prototype for office building in a tropical city' [1]. Unfortunately, as soon as the building was completed, its expatriate occupants partitioned off the open plan office and installed air-conditioning units. Thus the building was never used in the way which was intended and its many design innovations were ignored and soon forgotten.

The building is sited in a busy commercial district between Darley Road and the southern tip of the Beira Lake and overlooks Colombo's Hyde Park and houses a bank on the ground floor with offices on the upper floors. The two topmost floors are shielded by a floating canopy and served as an office and entertainment suite for the minister. The roof itself was used as a helicopter landing pad for the minister. Office spaces were designed as open plan with a minimum number of interior columns. The construction employed an insitu reinforced concrete frame which was strongly expressed on the elevation, and floor spans which were considered quite daring at the time. Windows stretching from column to column enclosed the office floor to bring in natural light to all parts of the space. The building was designed for natural lighting and ventilation. Suspended ceilings were omitted in order to reduce cost.

2. DESIGN PRINCIPLES

2.1 Building Shape and orientation

The site was an awkward and irregular shape, wedged between the Beira Lake and Hyde Park. Bawa exploited this, however, in order to create a plan form which would respond aerodynamically to the prevailing winds while reducing solar gain, and which would give a maximum footprint, thus reducing the number of floors. The resultant profile also results in an elegant building that changes dramatically when seen from different angles. It appears slender from certain angles and much broader from others.

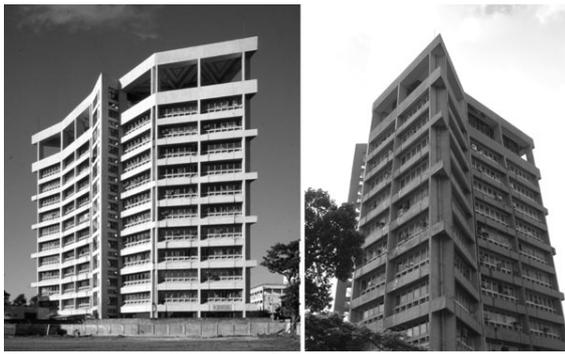


Figure 1: A building profile that changes dramatically when viewed from different angles.

The building facades face predominantly north and south to minimize solar gain which is important in the tropical climate and the orientation of the building is such that Northeast and Southwest monsoon winds can be maximised for ventilation. It also has an aspect ratio in its built form and a ratio of volume to surface that are within the recommendation for an energy-efficient building in the tropics [3].

Anura Ratnavibushana from Bawa's firm who co-developed the design, mentioned that he studied American office design standards to ensure that the office plan could achieve best efficiency of at least 80%. He was also concerned that there should be minimum number of columns in the office interior space. The top floor is designed with a Corbusian-type terrace open on all sides with a great view of the surrounding where social functions could be held.

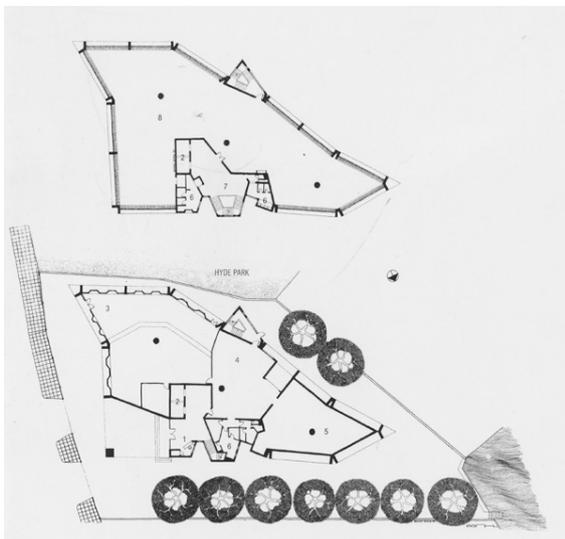


Figure 2: Site plan and floor plan.

2.2 Low tech and high rise

Colombo still had an undeveloped infrastructure when the building was designed. Electricity supplies were unreliable and lift breakdowns commonplace. Designing a building that goes higher with smaller footprint is less sustainable than one that has lesser storeys with a larger footprint. A 12-storey building's energy consumption would not impose such a great strain on the city's infrastructure as opposed to a slim but tall office block. Should the lift break down due to

a power failure, it is still practicable for occupants to walk down the natural lit staircase and be able to see their way. During that period, the import of building materials to Sri Lanka was severely restricted. The building was designed and built with local materials in mind. The floor was finished in polished cement rendering, window frames were made of timber and ventilation grilles were constructed of precast concrete.

2.3 Natural ventilation and day light

To achieve perpetual natural ventilation, Bawa designed an interesting and clever cross section that allowed for air movement at different body levels. Above the windows are precast ventilation grilles on the external walls. These are protected from rain penetration by an overhanging floor slab with a down-hung fascia parapet. Vertical pivot windows and horizontal precast concrete ventilation slots at sill height allows for ventilation at the body level. These horizontal ventilation slots allow unimpeded airflow into the building even if the windows are closed (see figure 3). In Sri Lanka, a similar strategy is used in schools but the detail was a much simpler one. Here, Bawa developed this idea of allowing air in and yet still protected from rain with a more complex cross section. The original sketch shows openable windows below the window sill which would have allowed low level ventilation but they were not implemented because the structural beams got in the way.

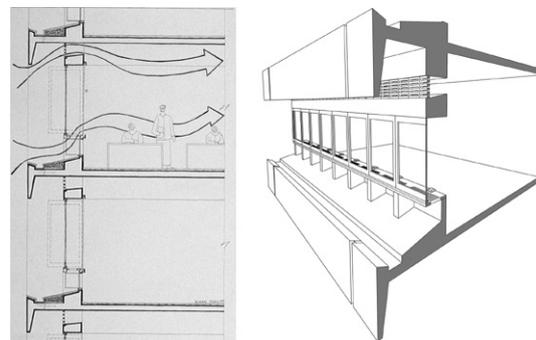


Figure 3: Original sketch section on the left. As-built section on the right without below-sill window.

The walls between office space and lift lobby have high level precast ventilation holes that allows good cross ventilation of the office space as the air flows from exterior windows to the lift lobby or from staircase windows through the lobby into the office space. The lift lobby and all stair cores are located on the perimeter of the building so that they are well lit and ventilated. When the authors visited the building, they found the lift lobby airy and bright without necessity of artificial lighting. Providing a view out of the building also makes the lobby a more welcoming space.

The staircases were originally designed to be open on the sides but openable windows were added later to cut out rain. Bawa's decision to locate the staircase, lifts and toilets at the perimeter rather than in the centre core was led by pragmatism and instinct but it anticipated the theoretical and scientific work of Ken Yeang when he developed design principles for

tall bioclimatic buildings [3,4]. Yeang stated that peripheral service cores provide many benefits. They eliminate the need for mechanical ventilation and fire-protection pressurization duct (prevalent in internal core staircases); provide natural ventilation and light to the lift lobby and stairs thus resulting in lower energy consumption and lower operating costs; provide a view out with greater awareness of place for users; and are a safer building in the event of power failure. One of the author's own office building designs - Revenue House in Singapore – used twin peripheral cores and confirm these advantages. In terms of annual use of kilowatt-hours per square metre, it consumes about 30% less energy than the average building and won the most Energy-Efficient Building in ASEAN in 2000 [5]. Studies have shown that the energy load of a naturally ventilated office is only half that of air-conditioned office [6].

The office plan is of shallow depth and meets recommended standards for good daylight penetration [7]. The column-to-column perimeter windows allow daylight into most parts of the office space all times of the year. Studies have shown that using daylight can reduce energy use for lighting by about 60% compared to a totally artificial lit space [8].

2.4 Reducing solar gain and radiation

The main elevations face predominantly north and south to reduce solar gain. They also work well in the monsoon climate with longer facades oriented to face the prevailing winds and allow breeze into the building. Solar control is achieved through the use of deep horizontal overhangs that act as sunshades. Down-stand fascias cut out the low angle sun most months of the year as seen in computer daylight studies in figure 4 and 5.



Figure 4: Computer daylight studies. On 21 June, the overhang and down-stand fascias cut out low angle sun.



Figure 5: Computer daylight studies. The sunlight penetration at 3pm on 21 December.

The design adopted a twin core layout. The cores serve as solar buffers, reducing heat gain into the building. The main core consists of lifts, staircase, toilets and entrance lobby that are all naturally ventilated. The lobby is very bright and airy and offers views of the city. The secondary core houses the escape staircase which is also naturally lit and ventilated with openable windows.

2.5 Attention to details

Bawa was also very attentive to details. He selected pivot windows because of the practical need to clean the glass from within. Vertical pivot windows were preferred over horizontal because they will not fall off easily as their loads are kept on the sill. He also designed sloping surfaces and gutters on the overhanging floor slab to discharge rainwater into pipes hidden behind U-shaped columns and instructed Ratnavibushana to add in grooves in the facades to prevent the façade from streaking.

3. DISCUSSION

The world today is facing an escalating energy crisis and there is a growing need to develop sustainable designs for office buildings. What lessons can this building of the 1970s offer for today's context? This section will discuss some of the shortcomings of this building in today's context and what could be done to rectify them in order to keep to the original intent of a naturally ventilated and lit office.

Surprisingly, by today's measure of best practices of green or ecological buildings, this building would be considered as one. For example this building meets most of the critical parameters for a Green Office [6]. Its window to core distance does not exceed the range of 6m to 12m and thus allows the office to be daylit most of the day. The deepest plan depth is well within the depth of 13.5m to 15m recommended for draught-free cross ventilation. This building also meets most of the guidelines for designing ecological and sustainable skyscrapers [3,4] and Hawkes environmental design checklist for "selective design" [8]. In Hawkes definition, "selective design aims to exploit the climatic conditions to maintain comfort,

minimizing the need for artificial control reliant on the consumption of energy.”

The building was designed before the wide-spread use of air-conditioning in Colombo. It was never used as originally intended – open plan, naturally ventilated office building. It was air-conditioned once the expatriate occupants moved in. Currently, the departments of the Mahaweli Authority occupy the building. It was in a sad state when the authors visited the building in 2005. At ground level, high walls and barbed wires enclosed the compound due to security reasons. Ugly window unit air-conditioners dot the façade of the building and curtains were drawn in the office interior cutting out natural light. The office interior is divided up haphazardly by internal partitions into separate departments. There are some shortcomings of the building that results in its current state. However, the authors believe that with monitoring of the building performance and modification of details, these shortcomings could be overcome.

3.1 Noise and dust

The occupants complained that dust and traffic noise prevented them from opening the windows for natural ventilation. Paradoxically, however, it was clear that more windows were opened on the lower floors and the occupants there seemed to prefer natural ventilation. The main problems were skylglare and paper flying about. The building was built before Colombo's central business district experience a building boom and growth in car population. However, noise control could be addressed through use of acoustic shelves on the exterior and acoustic panels on surfaces inside.

3.2 Ventilation control

Occupants also mentioned that when windows are opened, especially on higher floors, papers sometimes fly about, making it hard to work. As a consequence they left most windows closed. The ventilation could be improved by modifying the design of the windows so as to better regulate airflow.

Most of the ventilation slots on the horizontal window sill have been covered with plywood boards to prevent fine rain spray being blown in during heavy monsoon showers and to prevent leakage when the air-conditioner is turned on. Keeping the windows closed with the window air conditioning units on is not very effective as there is no proper fresh air change and the window units are not powerful enough to cool the large space. On certain floors, occupants still open up windows as the air conditioning is not cool enough or it is too stuffy in the office. This problem could be rectified with use of ceiling fans and through innovative detailing of slideable cover over the ventilation slots that can regulate airflow. An interesting detail has been used recently in a high-rise private apartment design at One Moulmein Rise, Singapore by Singapore architect firm WOHA that works well to regulate air flow and stop the rain from entering (see figure 6). With today's advance mechanical and air-conditioning system and wide range of building materials, it is possible to use a

mixed mode of natural and mechanical ventilation for the building during hot season.



Figure 6: Monsoon window at One Moulmein Rise, Singapore, with slideable panel to regulate airflow.

3.3 Glare control

It was unfortunate that the occupants use thick opaque cloth curtains in the office floor that cut out daylight and resulting on reliance of artificial lighting in the day time. The problem was one of glare. This could be overcome with use of perforated blinds, roller shades or exterior shading devices to reduce the glare.

3.4 Office Layout

Though the office is designed as open plan, the current occupants work under a hierarchical organizational structure. There is a misfit between open plan space and the organisational structure. The interior is partitioned up into rooms for higher ranking officers and full height partitions to separate the different departments. The irregular building plan is not suited for many internal partitions and the office interior is now like a maze. These full height partitions cut out natural light into the office interior and obstruct airflow. An ideal layout will be an open plan office using low screens for privacy and limited number of full height rooms near the core walls for very senior officers.

4. CONCLUSION

Conceived some 34 years ago, this project could be viewed as a brave attempt to create a prototype for low energy high-rise design in a tropical city. It was designed before the wide-scale use of air-conditioning in Colombo, and was configured to reduce solar gain and maximise the possibilities for natural ventilation. In scaling the tower at twelve storeys the designers were also mindful of problems of infrastructure load, and congestion whilst anticipating the need for higher plot ratios in the city's burgeoning down-town area.

The design was overtaken by events surrounding the 1977 parliamentary elections which resulted in the formation of a progressive free-market oriented government. The original building client was replaced by the newly created Mahaweli Development Ministry which employed large numbers of expatriate consultants. These demanded air-conditioned office

spaces and the building's innovations were never properly tested.

No post evaluation studies were carried out after the State Mortgage Bank building was occupied. Without such studies it was not possible to modify any details or to learn from any mistakes. Discouraged, Bawa lost interest in the project and omitted it from subsequent publications. Consequently it was never published until it appeared in an article by Robson and Daswatte in 1998 [9]. Malaysian architect Ken Yeang only happened on it by chance when on a visit to Colombo.

Today energy guzzling towers with sealed glass curtain walls dominate Colombo's main business district, largely in response to the demands of overseas property developers and international clients and the lessons of the State Mortgage Bank have been forgotten.

What relevance does the building hold for today? A prototype 'green' building as defined in today's terms, already existed some 30 years ago, demonstrating a common sense approach to the design of office spaces in a tropical city. Bawa's approach to site, materials, to environmental design and to building form suggest that he was practising sustainable architecture long before the term was a buzz word in architectural design.

The State Mortgage Bank Building offered an alternative route to a previous generation of developers, but it was ignored. Developing countries such as Sri Lanka are now facing the brunt of the hike in oil prices. The building's untested innovations could still prove to be relevant as the latest energy crisis leads us to question current assumptions about air-conditioning. At the very least the design offers a starting point for any attempt to develop new ways of designing low-cost sustainable office buildings in developing countries.

ACKNOWLEDGEMENT

We would like to thank Anura Ratnavibushana for granting us an interview, Lunuganga Trust for permission to use Bawa's drawings, Daniel Hii for his computer renderings and National University of Singapore for their research grant R-295-000-052-112.

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