

The Glass Thing

A Study into Climatic Design Issues of High-rise Buildings in Nairobi, Kenya

Vincent Owiti

Architect

Mutiso Menezes International, Architects And Interior Design Consultants

Abstract

This paper traces briefly the evolution of high-rise buildings in Kenya and notes that glass has become the exterior finish of choice.

As a background, traditional methods of climatic design viz.: Mahoney Tables, Givoni Charts and Solar Diagrams are used to analyse various issues of climatic design.

DEROB, a computer simulation programme is used to analyse various hypothetical cases in a design to find the best alternative among the various options.

The results are discussed and the author highlights areas requiring further research and /or clarification

A conclusion is arrived at but given that design is all about choosing the best option in a myriad of parameters, the author does not pretend to issue "commandments".

Introduction

Geography⁽¹⁾

Kenya is located on the East Coast of Africa, with the equator running almost straight through the middle of the country (see fig 1)

Kenya attained her independence from the British rule in 1963 and is currently a member of the Commonwealth of Nations. 42 communities occupy this land of 580,000 sq. kilometres. Kenya has an estimated population of 30 million people.

Kenya has a great diversity of physical features and climatic regions that can be distinctly divided into 5 regions.

A) **Low Lying Arid and Semi-Arid Area**

This is found in the northern and North- Eastern regions of the country. It covers nearly two thirds of the country and is a hot and dry country with scarce water resources.

B) **The Coastal Belt**

This runs along the Indian Ocean from the Kenya Tanzania border to the Somali border. It is a well-



Fig 1. Map of Kenya

watered area that receives rain twice a year from the North -Easterly and south -Easterly monsoons.

C) **The Nyika Plateau**

This occupies the country between the coastal belt and the central highlands. It is a dry area of low rainfall and can be described as a dry savannaland and supports most of Kenya's world famous wildlife.

D) **The Central Highlands**

This is the most productive area of Kenya agriculturally. It is a raised volcanic block split from the north to south by the Great Rift Valley, an 8700 Kilometre ditch on the surface of the earth.

Mt. Kenya, the 5199 metre high mountain that is the only spot in the world where snow is found on the equator, dominates the eastern wall of the Rift Valley.

A combination of good rainfall, soil, and suitable climate makes the region one of the richest agricultural lands in the world.

E) **Western Slopes And Lake Basin**

These include the Mt. Elgon region and the Lake Basin, a low-lying area surrounding Lake Victoria, the second largest fresh water lake in the world.

This area is hot and moist and receives heavy rainfall from the lake. The vast mass of the lake water creates its own local weather systems.

Kenya is the world's 3rd. largest producer of tea and the no. 1 producer of pyrethrum, a crop used in the manufacture of insecticides.

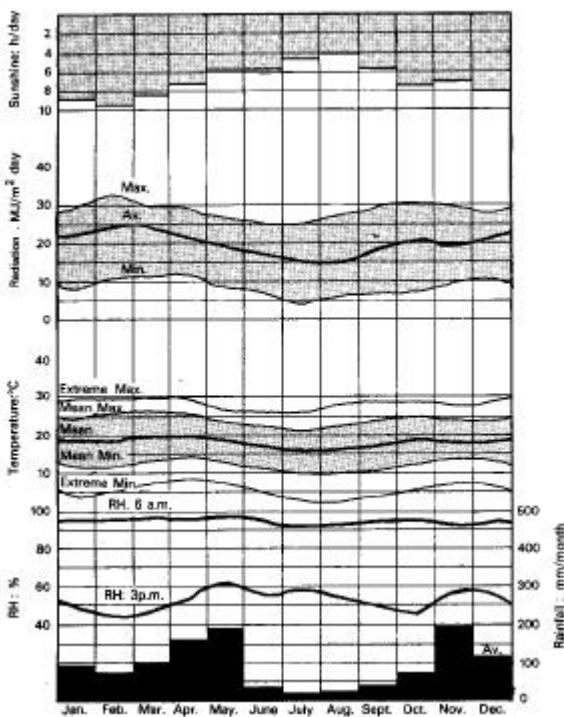


Fig. 2 Climatic Data of Nairobi

Climate

Given that Kenya's climatic regions are so diverse; the author will only present the climate of Nairobi, which is the region deeply studied in this report.

Nairobi is in the **CENTRAL HIGHLANDS REGION**. Illustrated above is the climatic data of Nairobi, a town classified as tropical upland climate (2)

It should be noted that the hottest month is February and the coldest month is July. The heaviest rains are experienced in April and May.

Architecture and Construction Techniques

A) **Traditional Architecture**

Kenya's traditional architecture was not homogeneous but a mirror of the diversity of the communities that live in this land.

It would be futile explaining the built form without explaining the sociological context and use of the buildings.

The traditional house types developed in response to the needs of a predominately peasant population. The surrounding country provides the building materials; in humid tropics, timber, bamboo, and thatch, in arid zones, stones, earth and brick and in composite climates a mixture of organic and inorganic materials. Everybody is a house builder as much as he is a cultivator or a herdsman. Traditional rural building is based on low investment and high maintenance. (2)

Since people spend most of the day in the open, the functions of the huts and houses are reduced to three; shelter from rain, spells of extreme heat or cold, minimal privacy and safe storage of possessions.

It is important to note that a house was not merely satisfying a practical need was also a cultural obligation and a status symbol in most communities.

The communities in Kenya constructed their buildings with a variety of materials but mostly a combination of thatch, mud, and timber.

The building materials used had good Thermal capacities and thermal insulation properties.



Fig 3 Luo Traditional House (Note the mud walls and the grass-thatched roof)



Fig 4 Taita Resting Hut
Note the thatch throughout the building

B) Modern Architecture

“Modern” architecture in Kenya can be analysed in two distinct aspects.

i) Rural Architecture

The Modern Kenyan associates the traditional hut with “primitives” and poverty. Those who continue building these traditional houses do so largely due to insufficient finances to build a modern house, read corrugated iron sheets on the roof and stonewalling.

Despite the preference of these new materials, the rural population, consisting mostly of peasants, can ill afford the thermal insulation required to make these materials climatically sympathetic, especially the corrugated iron sheets.

Even in instances where local materials are used, the form of the building has changed to accommodate the rectilinear furniture now used all over Kenya. For example in the Luo, the form of the building has changed from round to rectangular.

ii) Urban Architecture

In the urban areas, the design of buildings is pretty much like elsewhere in the world.

A housing estate in upmarket Nairobi for example, is not very different from those in any developed country.

There is however a very high dependence on manual labour as the construction process is less industrialised. This is very different with say Sweden where the author has noted a high dependence on machines in almost all facets of the construction industry.

A detailed analysis of the urban buildings, with specific emphasis on the high-rise buildings is given here under:

Since the colonial time, the architecture in Nairobi has followed the trend elsewhere in the world. Initially there was the colonial Architecture characterised by a strict adherence to proportions, repetition and grandeur.

(3)



Fig 5 High Court of Kenya



Fig6 Chai House, Nairobi

After the colonial period, most buildings were designed with an evident emphasis of the sun shading elements, a conscious effort to avoid glare, especially on the East-West facades. There is also a romantic indulgence with fair-faced concrete or bush hammered facing.

While being pragmatic, this style also offered the Architects a chance to revisit the classical tenets of proportions, repetition and grandeur.

Some buildings designed during this period have been regarded as monuments in the City by many an observer. For example, a commentary of Nairobi’s Architecture would be incomplete without mentioning the Kenyatta International Conference Centre. While this building can be classified in the above category, it has been noted for its success in using “Historical Recall”, a synthesis of traditional form and urban design principles that give it an imposing stature in the Nairobi skyline.



Fig 7 KENYATTA INTERNATIONAL CONFERENCE CENTRE
Note the "hut" on the podium

Since the late 1980s however, any visitor to Nairobi will notice a remarkable increase in the number of buildings coming up in glass cladding. There is an evident indulgence in finesse (6) the focus shifting from a more rustic image in vogue earlier on to a "sparkle finish". These are ornaments in the skyline.

This is what the author refers to as **THE GLASS THING!**



Fig 8 View Park Towers

Problem

Ordinary glass, by its very nature has poor thermal properties... ill suited for tropical climates. Glass has high Transmittance of short wave radiation, and low transmittance of long wave radiation. Special glass however ameliorates these properties, especially transmission.

Excessive use of glass in facades therefore leads to poor indoor climates. There is a need to cool buildings during hot days as the glass transmits the short wave radiation from the sun and yet is almost opaque to radiation from inside the building (long wave radiation).

In cold seasons, the low thermal insulation results in cold climate. The glass does not store the available heat long enough to re radiate the same when most needed. This necessitates heating in some cases.

These properties result in high-energy consumption in buildings thus increasing the running costs of the buildings and straining the scarce national resources in developing countries.

A general lack of understanding of basic climatic design issues by the average designer in Kenya has compounded the problem as good design and specifications can ameliorate the above-mentioned problems. For such a designer, design is approached from the elevation and form, all other issues are considered secondary.

The presence of ameliorating possibilities in itself has also been noted to be an inadequate excuse. The use of air-conditioning plants, for example to correct an ill-conceived environment does not differ in principle from the use of a masonry façade to hide an unnecessarily ugly concrete structure. The climate presents a challenge for the Architect not satisfied with substituting mechanical equipment for good design. (2) This is even more critical in developing countries.

It has also been noted that one of the basic needs of the human being is change and variation. Mechanically controlled environments such as air-conditioned buildings where the environment can be, and often is, kept within very fine limits do not offer this variation. Fortunately, buildings without mechanical environmental controls offer the possibility of these variations. (2)

However, the Architect cannot design in a vacuum, his clients are always a "design parameter" he must contend with. The excessive use of glass cannot therefore be wholly blamed on the architects. In this era of Information Technology and international travel, clients are exposed to designs from regions quite different from their own, but they like these designs all the same.

The sleek image is therefore fuelled by an excited clientele and public, acting as enthusiastic spectators from the terraces, cheering the designers do their thing in the urban field, oblivious, albeit ignorant of the environmental impact of these "masterpieces".

How then does an informed Architect walk the tight rope, balancing vogue on one hand and responsible climatic design on the other?

THIS IS THE CHALLENGE

Hypothesis

The climate in Nairobi is not adverse and therefore indoor thermal comfort can be achieved solely by passive means.

The improper use of the glass cladding is a major source of thermal discomfort of high-rise buildings in Nairobi

(Passive means in this case includes thermal insulation, thermal capacity, solar control, orientation, heat absorbing glass, reflective glass and blinds.) (2)

Method

Project Description

CLIENT: Victoria Towers Ltd.

ARCHITECTS: Mutiso Menezes International

Victoria Towers is situated at the junction of Kilimanjaro and Kenya roads in the Upper hill Area, Nairobi, Kenya. This is an area that has been predominantly residential but is rapidly changing to commercial with many corporate organisations exploiting the pioneering status to develop “showpiece” architecture for their accommodation. (6)

The building, which is currently under construction, will accommodate shops on the ground floor, a Bank on the mezzanine and first floors and office spaces for sale in the rest of the floors.

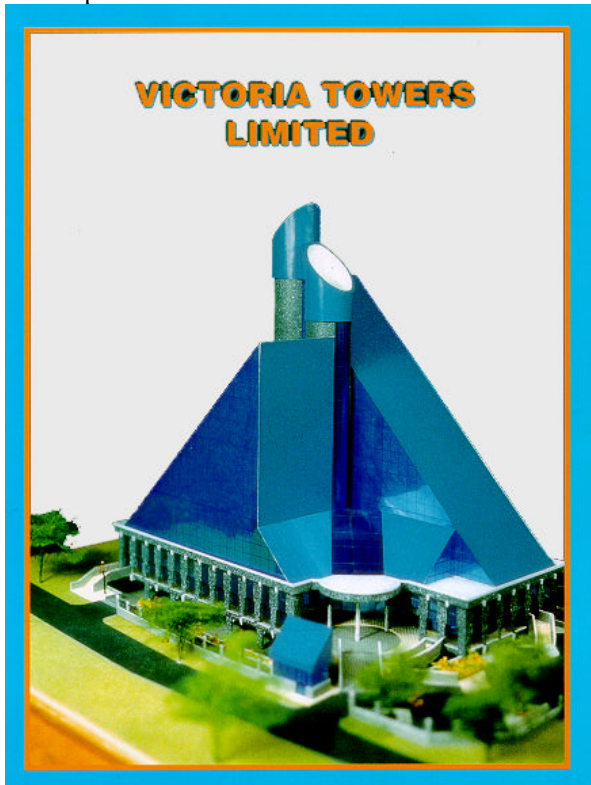


Fig 9 Victoria Towers, Nairobi

The form, conceived to echo a boat “floating on Lake Victoria”, is a staggered wedge shaped twin tower in blue curtain walling sitting atop a rustic rectangular base in textured cladding. (6)

The facades of the wedge shaped towers are oriented North-South to “minimise sun penetration to the offices”. **Blue reflective curtain** walling to these facades further mitigates sun penetration and glare. The East-West facades are **double glazed** to ensure a comfortable internal environment. (6). The sloping surfaces are in **RC. Slab** clad in blue ceramic tiles

The total floor area is **110,757sq. Feet**. Given the wedge shape of the towers, the areas of floors differ. The northern wing of seventh floor will be analysed in this study.

Studied Parameters

Traditional Methods

The scheme was analysed using the Givoni chart and Mahoney table. The Giovanni Chart and Mahoney table is attached in the appendix. Results from the same are highlighted here under.

Modern Methods

For the modern methods **DEROB-LTH was used**. Dynamic Energy Response Of Buildings (DEROB) is an environmental design computer simulation programme consisting of 8 modules, 6 of which are used to calculate values for temperature and cooling loads.

The calculations are performed in a dynamic way for each hour during a specified period of simulation. The calculations are influenced by climatic factors such as outdoor temperature, solar radiation and sky temperature.

DEROB-LTH was originally developed at the Numerical Simulation Laboratory, the school of architecture, University of Texas at Austin. It was further developed at the Department of Building Science at Lund Institute of Technology. In order to analyse this building, the northern wing of 7th. Floor is taken as a typical floor.

Since this is a high-rise building, it is assumed that the thermal conditions of typical floors are similar.

Therefore, no heat exchange is anticipated between the seventh floor and the 6th. Or 8th. (Adiabatic Slabs) Floors.

Given the depth of the building and to simplify the model, the walls towards the circulation core will also be assumed to be adiabatic

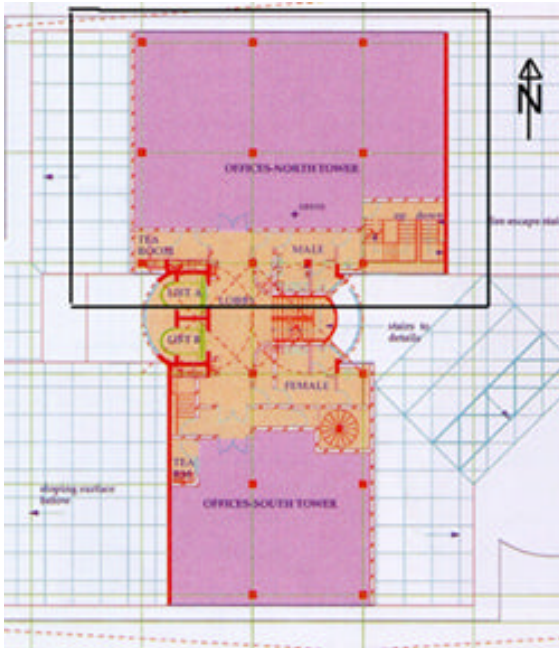


Fig 10 Existing Seventh Floor Plan

The DEROB Model

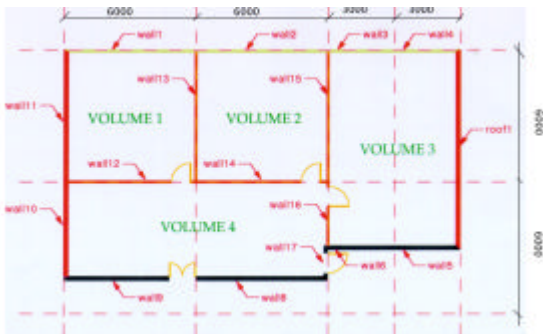


Fig 11 Assumed Seventh Floor Plan

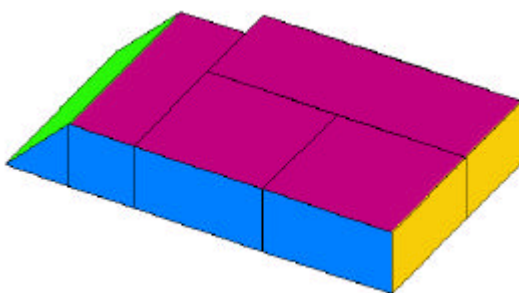


Fig 12 Derob 3D Model

- i) The floor slabs are Adiabatic (no heat exchange between various floors)
- ii) Walls 5,6,7,8 and 9 are adiabatic
- iii) Walls 10 and 11 are on the western façade and are altered as per the various cases
- iv) Walls 1,2,3 and 4 are on the northern façade and are altered as per the various cases.

- v) Roof 1 is part of the sloping surface as per fig 12 and is constructed in sloping RC slab finished in plaster on the inside and blue ceramic tiles on the outside. The angle of slope is 45 degrees.
- vi) The air infiltration in VOLUME 1 is 6 Air Changes per Hour (ACH) from 18hrs to 8 hrs (at night) and 10 ACH from 8hrs to 18hrs (when the building is in use)
- vii) The air infiltration in VOLUME 4 is 3 Air Changes per Hour (ACH) from 18hrs to 8 hrs (at night) and 6 ACH from 8hrs to 18hrs (when the building is in use)
- viii) 4 persons producing 100W each occupy each volume. Each person is assumed to be working with a computer producing 100W.
- ix) The comfort zone is between 20°C-25°C during the day.
- x) The windows will NOT have curtains or blinds
- xi) Floor to ceiling height is 3000mm.

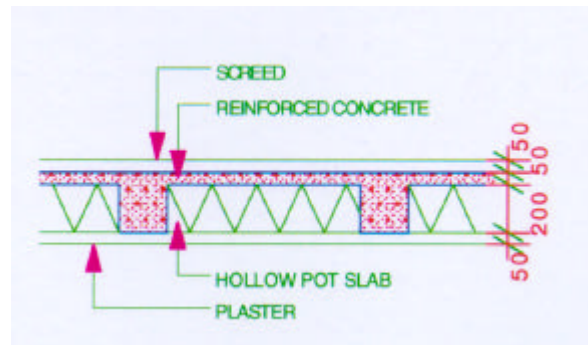


Fig 13 Existing Floor Slab Construction

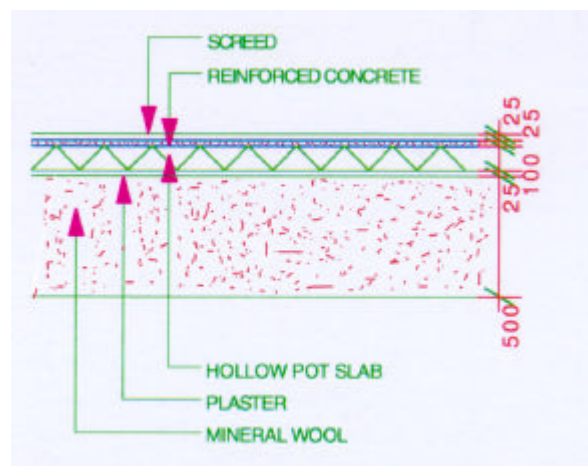


Fig 14 Assumed Floor Slab Construction (Adiabatic Slab)

Adiabatic walls are conceived using the same principle.

The following thermal properties for the various construction materials were assumed.

Material	Density Kg/m ³	Conductivity W/ mK	Specific Heat Wh/Kg. K
Concrete	2100	1.28	0.26
Mortar	1800	0.93	0.29
Hollow Pot	1000	0.50	0.26
Mineral Wool	50	0.04	0.24
Chipboard	300	0.05	0.39
Plywood	500	0.14	0.75

Fig 15 Thermal Properties of Construction Materials.

The following properties were further assumed for glass (at 90° angle of incidence). The figures below are expressed as %

Type Of Glass	Emmit -ance	Transmi -sion	Reflecta -nce	Absorb -tance
Ordinary (Kappak)	84.5	82.0	7.0	11.0
Heat Absorb.	90	43	5	53

Fig 16 Properties of Glass.

The depth of the air gas in the double glazed window was assumed to be 50mm.

The studied parameters include the effect of type of glass, masonry walling, and sun shading on the energy consumption for cooling and heating of buildings

The following hypothetical cases were analysed:

1) **Baseline Case:**

- a) Northern wall has ordinary glass,
- b) Western wall is in masonry structure
- c) All the partitions are in chipboard finished with plywood on both sides.
- d) The sloping roof is in RC concrete structure.
- e) The slabs and walls that are adiabatic are stated in the “DEROB Model” above.
- f) Volume 1 and volume 4 are studied
- g) Temperature Graphs generated

2) **Case 02**

Ditto as case 1 but:

- h) Northern wall has heat-absorbing glass in lieu of ordinary glass, the aim being to analyse the effect of quality of glass on indoor temperatures.

3) **Case 03:**

Ditto as case 2 above but:

- i) Western Wall has double glazed heat absorbing glass, the aim being to analyse the effect of having double-glazing in lieu of masonry wall on the west facing façade.

4) **Case 04**

Ditto as baseline case but:

- j) Northern wall has ordinary glass, but sun shaded appropriately, the aim being to analyse the effect of sunshading on indoor temperatures.

In all cases, the studied period will be in the months of July (the coldest month) and in the month of February (the hottest month).

Results

Climatic Analysis

The Givoni Chart

The climate is analysed using the Givoni chart and the result is as hereunder. It shows from this graph that the climate in Nairobi is reasonably comfortable. Sufficient internal gains and ventilation can correct any discomfort.

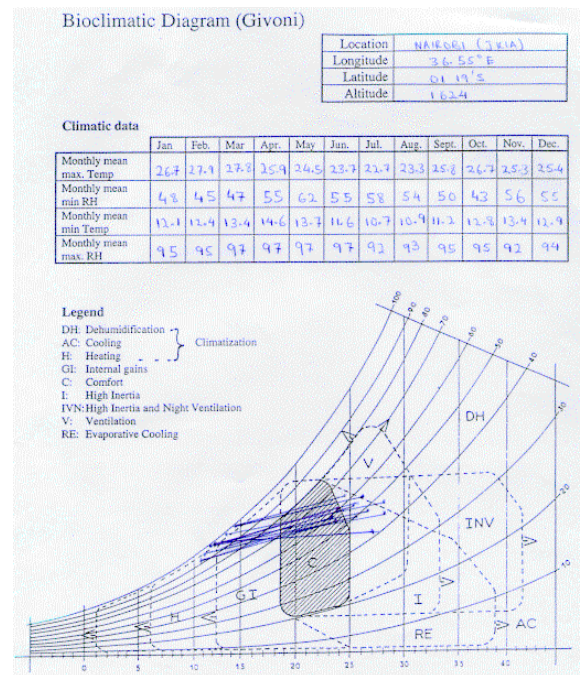


Fig 17 The Givoni Chart.

Analysis of Results from Traditional Tools

Mahoney Table Analysis

The Mahoney table analysis is attached in the appendix. The following recommendations are arrived at.

- i) The orientation should be north south (long axis east-west)
- ii) Open spaces should be allowed for breeze penetration but protection should be provided from hot and cold winds.

- iii) Rooms should be single banked with provision for permanent vents.
- iv) Large openings (40-80%) are recommended.
- v) Walls should be light with short time lags.
- vi) Roofs should be light and well insulated.
- vii) Openings should be on the north and south walls at body height on windward side.
- viii) Direct sunlight should be excluded.

Solar Chart Analysis

The northern facing façade is analysed. From the solar chart, it is clear that for one to achieve maximum shading, the angle that is critical falls in the month of June. Total shading can be achieved in June by having horizontal sunshading elements that provide a solar zenith of 65° and vertical elements that cover the solar azimuth of upto 60°. A horizontal shading of approximately 800mm. Projection from the wall covers the facade from 9.30am to 4.30pm. to sunshade the façade totally for the purpose of this study, vertical sunshades at 1000mm. Centres cover the building from 6.00am to 9.30am and again from 4.30pm to 6.00pm

In the case where DEROB is used (modern tool), only Volume 1 and Volume 4 will be analysed. This is because volume 2 and 3 are facing the similar conditions like volume 1 and the result in volume 1 will be taken to be representative of volume 2 and 3.

Results From Modern Tools

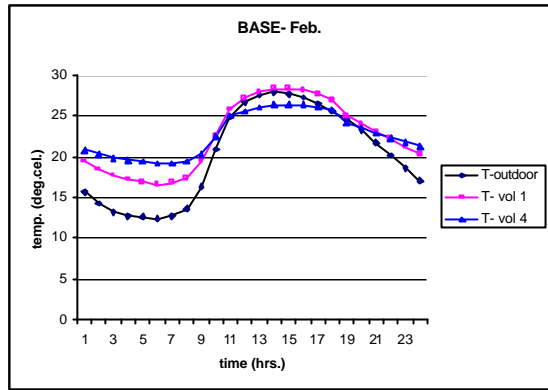


Fig. 19 Temperature curves-Feb. base case- (ordinary glass)

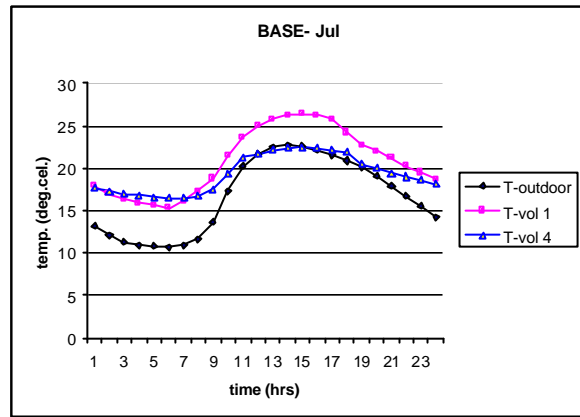


Fig. 20 Temperature curves-July. Base case- (ordinary glass)

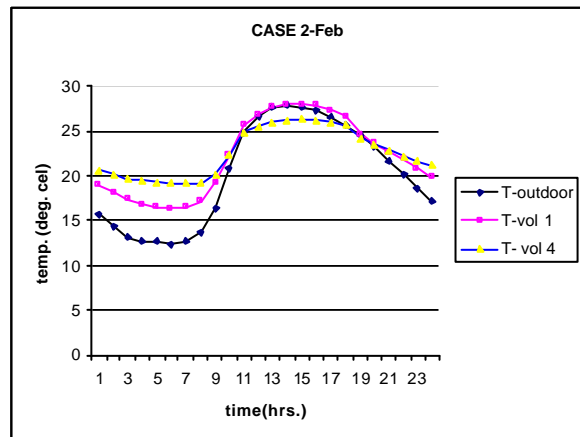


Fig. 21 Temperature curves-Feb. case 02- (heat absorbing glass)

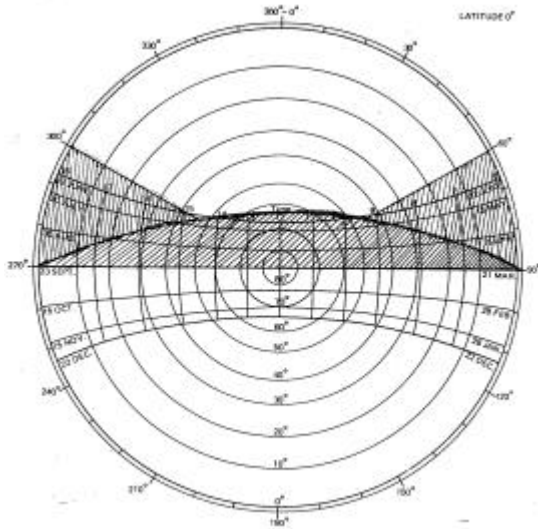


Fig. 18 Solar chart, northern façade.

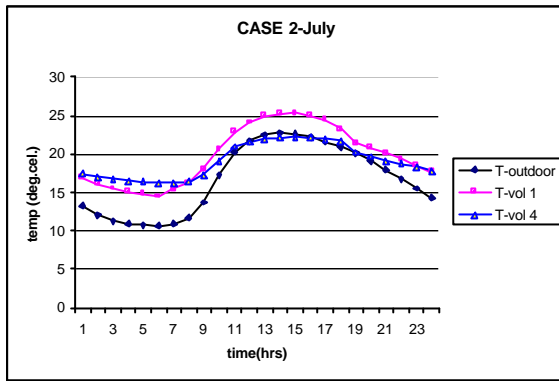


Fig. 22 Temperature curves-July. Case 02- (heat absorbing glass)

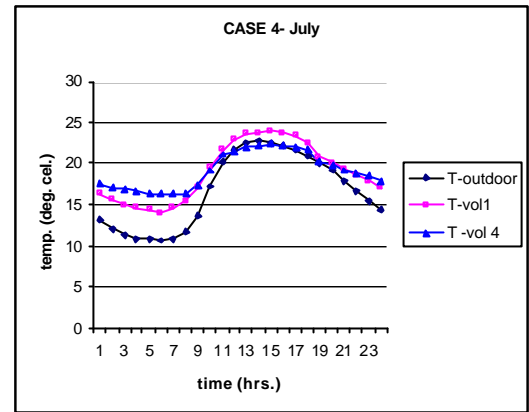


Fig. 25 Temperature curves-Jul. case 04- (sunshading on northern wall)

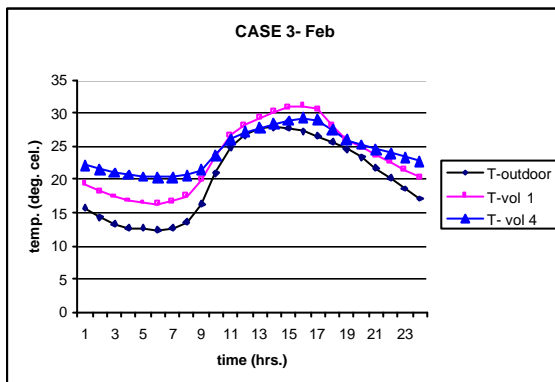


Fig. 23 Temperature curves-Feb. case 03- (Western Wall double glazed, northern wall has heat absorbing glass)

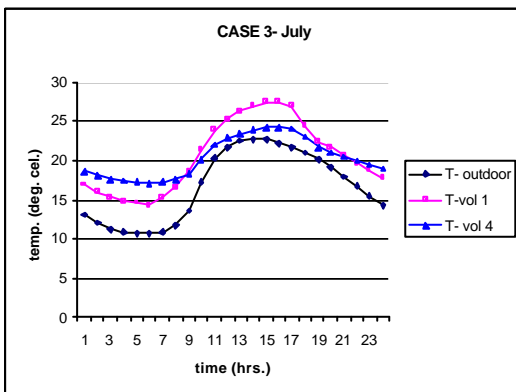


Fig. 24 Temperature curves-Jul. case 03- (Western Wall double glazed, northern wall has heat absorbing glass)

Discussion

General Discussion

The study was an eye opener to the author in many respects. It highlighted some salient issues not previously clear cut to myself.

From the climatic analysis, it is apparent that Nairobi enjoys a good climate (fig16).

The Mahoney tables analysis provides a good guideline for design, more like a rule of thumb.

However, the recommendations are so broad that in some cases they are superfluous. these recommendations in some cases do not recognize the peculiarities required in certain projects. For example, advising a designer to have single banked design in a complex project, or even in an upmarket residential house is impractical, architecturally.

Another surprising recommendation in Mahoney Tables is that the walls should have a low time lag while it is more reasonable to even out the diurnal range by having higher time lags. Indeed, the Givoni chart clearly shows that nights tend to be cold and the days hot. Even the Mahoney Chart shows this.

DEROB is noted for its specificity. The fact that thermal properties of various items are taken into account offers unparalleled opportunity for a designer to analyse each project in a very specific manner.

It was also noted that DEROB complements traditional tools, for example the results obtained from the solar charts can quickly be verified and refined in the solar view in DEROB.

Discussion of Results

It was noted that the temperatures in volume 1 were higher than the temperatures in vol. 4 during daytime and vis vis at night. This can be easily explained from the thermal insulation vol. 1 offers to volume 4.

The temperatures obtained in volume 1 will therefore be analysed hereunder to give an insight into the factors that come into play .

Only maximum temperatures will be analysed as the building is essentially an office block and is therefore used during the day.

Given the minor difference between operative temperature and air temperature, only the latter shall be used in this analysis.

Maximum Temperatures

CASE	Temp outdoor	Temp. indoor (volume 1)	Degrees Outside comfort
BASE-feb	27.9	28.1	3.1
Base-Jul.	22.7	26.4	1.4
Case2- Feb	27.9	28.0	3.0
Case2- Jul	22.7	25.3	0.3
Case3- Feb	27.9	30.1	5.1
Case3- Jul	22.7	27.4	2.4
Case4- Jul	22.7	23.7	In comfort

Fig. 26 Maximum Temperature Comparisons

In the base case (February), the maximum temperature is 3.1 degrees above comfort levels.

It is surprising that the use of heat absorbing glass (case 2 February) does not have an appreciable effect on this.

The heat absorbing glass in this case has a transmittance of 42%, nearly half the transmittance of ordinary glass.

A possible explanation is that heat absorbing glass is more effective for direct solar radiation than it is for diffuse radiation (in February, the sun is in the Southern Hemisphere and therefore does NOT directly heat the northern façade). This hypothesis needs to be investigated further.

This explanation is further supported by the significant reduction realised when heat absorbing glass is examined in Case 2 for July when direct solar radiation is received in the window (a reduction of 1.1 degrees is realised in this case.) The resultant maximum temperature in July is only 0.3 degrees above the comfort zone in case 2.

It is however clearly noted that the introduction of glazing on the western façade has a drastic negative impact on the indoor climate.

The double-glazing introduced in this case (heat absorbing glass 50mm thick air gap and ordinary glass) does not come close to the thermal properties of masonry walling on this façade. In February, the resultant indoor temperature is 5.1 degrees above the comfort zone, requiring a very high Energy Load if this space is to be made comfortable by Active means.

Effective sun shading is evidently a good solution as it is only in case 4 that the maximum indoor temperature is within the comfort zone (20-25 degrees)

The effect of sunshading was not analysed in February as the sun is in the Southern Hemisphere and therefore sunshading in this month would have no

consequence as there is no direct solar radiation on the northern façade.

Limitations

The author had intended to analyse the impact the various design solutions have on the energy consumption. This was not possible within the duration of this study.

It is further noted that the AIR CHANGES per HOUR have a very high impact on the results obtained and a detailed analysis of this should be carried out to obtain a more accurate picture of the issues at hand. This is even made more complicated by the fact that occupants can open and close windows and doors at will!

The ACH schedules were however kept similar in all cases in order to compare results on a level ground.

It should be observed that the ACH in February could easily be higher than in July as the presumably uncomfortable occupants of the analysed space would definitely open more fenestration.

The author did not have adequate time to investigate the impact of double-glazing on the northern façade and the effect of changing the specification of the double-glazing.

However, it should be noted that there is no case above where there is direct solar radiation on the glazed façade in February, but it can be deduced that the effect would be for the worse.

Further Investigations

The author intends to carry out further investigations on the impact of heat absorbing glass on diffuse radiation.

The compatibility of DEROB with other common Computer Aided Design software used by Architects should also be investigated, especially by the LTH research persons.

The Air Changes per Hour (ACH) is found to be an important parameter in the DEROB calculations and yet it is NOT part of DEROB. An analysis should be done such that a formula or simple rule of thumb to determine ACH can be developed, maybe even presented as a chart in the DEROB model.

The author intends to investigate the possibility of using one such software, ArchiCAD to simulate solar paths so effectively handled by DEROB. This would be very useful in the design of sunshading elements by many users of this software.

Conclusions

The design of high rise buildings in Nairobi would do with some enlightenment.

Glazing should be avoided on the east and west facades unless despite better judgement, the client sets out to have an artificially controlled building in the first instance.

The properties of “heat absorbing” glass should be well understood by the designers so as to avoid using the same in the mistaken belief that they are designing adequately, the range of such glass is so wide. It should also be noted that glass with so low transmission also causes low daylight, leading to more energy consumption in lighting the buildings.

If the “sleek” image is so desirable, the architect should clad the building in glass. but such cladding should be on masonry walls or reinforced concrete in areas that high radiation is expected.

Heat reflecting glass “mirror glass” however has the negative effect of being a nuisance to the neighbours.

Sun shading should still be designed to be aesthetically pleasant if The Glass Thing is to be stopped on its tracks.

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Owiti,
Lund Universitet, Sweden
Oct. 1999

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