Green Building Handbook for South Africa
Chapter: Building Envelope and Water Conservation

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1 Building envelope

1.1 Introduction

Developing the right building envelope is an important part of designing green buildings. A well designed envelope can ensure that occupants of buildings have productive and healthy internal environments that do not require large amounts of energy.

This chapter describes the way building envelopes can contribute to developing green buildings and sets out some objectives that could be aimed for. It also proposes a number of approaches that can be used to help design green building envelopes. Finally, aspects of green building envelopes are described so that designers can select and work with the most appropriate of these to develop high performance green building envelopes.

1.2 The building envelope and sustainability

Building envelopes in green buildings are different from conventional buildings in that they aim to achieve a wider range of objectives and tend to work in a different way. Some characteristics of green building envelopes are described below:

- **Responsive:** Green building envelopes are designed to respond to their local context and work with external and internal conditions to achieve optimum environments within and around the building. Therefore the building envelope may have additional acoustic treatment in areas which receive noise from external environments and have strong visual and physical connections (through balconies, windows and external doors) where external light and thermal conditions support human comfort.
- **Dynamic:** In order to achieve optimum conditions on an ongoing basis, green building envelopes are dynamic and adapt to changing conditions. Thus more of the building envelope may have shading in summer than in winter to minimise unwanted heat gains. In winter the envelope may allow more sunlight to enter the building than in summer to allow this to warm the building.
- **Controllable:** Providing users with greater control over local environments is a central strategy in most green buildings. Building envelopes therefore are likely to have large numbers of operable windows that can be easily opened and closed by occupants. They may also have controllable internal blinds and external solar shading which can be used to maximise internal daylight quality and avoid glare and solar gain.
- **Ecological:** Green building envelopes aim to support the development of ecosystems and plant and animal life around building. Therefore the envelope may be used to create habitat for animals such as birds and the roof and balconies may be planted.
- **Breathing walls:** Designers of green building often try and achieve the same performance qualities found in good outdoor clothing. The outer layer of the building envelope, like a raincoat and umbrella, provide protection against weather such as wind and rain. The middle layer, like shirts and jerseys, provide warmth and thermal insulation. The inner layer, like a vest, is comfortable to touch and works away excess moisture.
- **Microclimate:** The building envelope is used to support the development of local microclimates. Thus, envelopes may be used to create sheltered, sunlit spaces around buildings as amenity areas for occupants. They may also be used to create vegetated, shaded areas from which cool, fresh air can be drawn into the building.
- **Energy:** Building envelopes provide excellent opportunities to generate renewable energy for use in the building. This is done through photovoltaic and solar water heating panels and wind turbines. Ideally these are integrated in the design of the building envelope to improve the aesthetic quality of the building and minimise material requirements.

1.3 Key performance objectives

Some performance objectives for green building envelopes are provide below.

Aspect	Performance Objective	Achieved?
Daylight	The design of the building envelope ensures that an average daylight factor (DF) of 2.5% is achieved in all occupied (living and working) areas in the building.	
Ventilation	The design of the building ensures that spaces can be naturally ventilated. A minimum openable area within the external envelope of at least 5% of internal floor area is provided for natural ventilation.	
Sunlight	Direct sunlight is avoided in office working environments, particularly where VDUs are used. Sunlight access into the building is only allowed into the building as part of a direct gain passive solar strategy where this plays a useful role in warming the building in winter.	
Air tightness	The building envelope is air tight in order to avoid unwanted infiltration of cold or hot air through the building envelope. Air tightness standards exceed the minimum standards required by SANS 204.	
Noise	Obtrusive external noise from traffic etc is not experienced in the building and internal noise levels do not exceed good practice standards (ie ambient sound levels not exceed 45dBAeq in open plan offices)	
Habitat and vegetation	At least 10% of the external building envelope has vegetation cover. This may be provided in the form of green roofs, window boxes, planted terraces and balconies and wall creepers. This is also used to support the creation of wildlife habitat.	
Thermal comfort	The envelope aims to achieve best practice internal thermal comfort levels as measured using the Predicted Mean Vote in ISO Standard 7730, Ergonomics of the Thermal Environment.	
Energy	The building envelope supports an overall integrated design strategy that achieves good practice energy consumption targets and significantly exceeds minimum energy efficiency standards listed in SANS 204.	
Car parking	All covered car parking spaces are naturally ventilated.	
Renewable energy	The building envelope includes renewable energy generation such as photovoltaics, wind turbines and solar water heaters and 10% of the building's energy requirements are generated from these sources.	
Views	All working spaces are within 7m of a window and have a direct view of the outside.	
East and West elevations	Windows on east and west elevations are minimized and appropriate solar shading is provided where this exists to avoid unwanted solar gain.	
Openable windows	Openable windows are provided where they can easily be controlled by people near them. At least one openable window per 5 running metres of building envelope is provided in occupied areas.	
Internal blinds	All windows in working areas are provided with internal blinds.	
Rainwater harvesting	Roofs are used for harvesting rainwater and a target of a 50% reduction in mains potable water consumption (relative to conventional buildings) is achieved.	
Cool roofs	Roofs and large external balconies and terraces are constructed of a material with an absorptance value of under 0.55 (are light coloured) to avoid unwanted heat gains.	
Insulation	Insulation values in the building exceed the minimum requirements outlined in SANS 204.	
Passive environmental control	The building envelopes support passive environmental control strategies as described in the passive environmental control chapter by providing correctly located and sized openings and thermal mass etc	

1.4 Working with building envelopes

There are a number of techniques that can be used to develop building envelopes that are appropriate for green buildings. These are described below:

- **Integrated design:** Developing the building envelope with all key design team members helps to ensure that high performance designs are developed. In this way Mechanical Engineers, Electrical Engineers, Structural Engineers Acoustic Consultants and Landscape Architects work with the Architect to ensure that suitable wall build ups and roof designs are developed, and windows and solar shading are appropriately sized, and located. This process helps avoid the situation where an Architect, working in isolation, unwittingly creates environmental control problems such as large solar heat gains which can only be solved through mechanical plant.
- **Large sections:** 1:10 sections of building envelopes are very useful in understanding the design of a building envelope and should be developed early in the design process and used to inform detailed design discussions. This process ensures that issues such as window jambs, cills, thermal breaks and solar shading are addressed early, resolved, and neatly integrated into final designs.
- **Modelling:** Increasingly, modelling is being used to test and refine building envelope designs. This can be used to rapidly test different envelope options in order to optimise natural day lighting as well as acoustic, thermal and passive ventilation performance. Where computer modelling is not available, or too expensive, physical modelling and calculations can also be used.

1.5 Aspects of green building envelopes

Outlined below are a range of aspects that can be used in the design of building envelopes to support the development of green buildings. It should be noted that care should be taken in integrating these into designs as not all of them are appropriate for all circumstances. They are provided here as a source of inspiration for designers, but should not be used in place of a thorough and integrated design process.

1.6 Materials

Care should be taken in the choice of materials for the building envelope. Key considerations should include the following issues:

- **Performance requirements:** Materials selected should ensure that the performance requirements developed for the building envelope can be met. These are described below under insulation, thermal mass and air tightness.
- **Local manufacture:** Materials and components should be locally sourced in order to minimise transportation impacts and create local jobs.
- **Environmental impact:** Materials with substantial negative environmental impacts, such as materials with high embodied energy, or material with harmful production processes, should be avoided.
- **Grown materials:** Grown materials such as thatch, timber and wool which are renewable should be used, where possible.

1.7 Thermal conductivity

Thermal conductivity is a measurement of how much heat will move through a given amount of material. Thicker layers of material with a higher thermal conductivity values will be required to achieve the same degree of insulation as materials with a lower value. Thermal conductivity values for a selection of materials are provided below.

Item	Thermal conductivity (W/mK)
Rock wool	0.03
Glass wool	0.03
Wool	0.04
Thatch	0.07
Compressed straw slabs	0.10
Softwood	0.14
Plasterboard	0.21
Glass	1.05
Brick	1.15
Stone (granite)	2.90
Mild steel	50

From The Green Building Hand Book

1.8 U-values and R-values

A U-value is the thermal conductance of a composite building element and is the reciprocal of the total thermal resistance of the element, the R-value. This includes the sum of the materials, cavity and surface air film resistance across the section of the element and is measured as energy flow through a unit area of the element per ^{o}C temperature difference across it (Wm2^{o}C).

The lower the U-value the better insulated the building element is. A well insulated building envelope supports energy efficiency by reducing unwanted heat gains from, for instance, the sun in summer and unwanted heat losses from the interior of the building during winter. R-values developed for the building envelope should exceed the minimum requirements set out by SANS 204.

Insulation in the roof of a building is particularly important because of potential heat gains in summer from overhead sun and heat losses in winter. Where possible, insulation should be located on the external face of buildings to ensure that thermal mass of an envelope can contribute to passive environmental control strategies in a building (see below).

1.9 Thermal mass

The thermal mass of the building envelope can contribute to the overall thermal mass of the building and be used in energy efficient buildings to store heat and 'coolness'. In winter, heat from the sun, people and equipment can be stored in the high thermal mass building fabric to reduce the requirement for heating in the late afternoon and early evening. In the same way, by flushing the building with cold night air, the thermal mass of the building can store 'çoolness' from the night reducing the requirement for artificial cooling in buildings during the day. To contribute to this effect building envelopes should ensure that high thermal mass materials such as brick, stone and concrete are exposed internally. In addition, openings in building envelopes should be appropriately located to either warm thermal mass or to allow this to cool.

1.10 Air tightness

The air tightness of a building envelope is important for comfort and energy efficiency. An air tight building envelope helps to avoid discomfort caused by draughts and reduces heat gains and losses as a result of uncontrolled air movement between the interior and exterior of a building. Typically, uncontrolled air movement in buildings is a result of:

- Poor construction.
- Gaps between components of the building envelope, such as between windows and walls.
- Gaps between opening windows and window frames and between doors and door frames.

Careful detailing, the selection of components and high quality construction can be used to improve the air tightness of building envelopes. Designers should aim to achieve at least the minimum air tightness performance requirements of SANS 204.

1.11 Internal humidity

As buildings become increasingly well sealed and air tight, internal humidity levels can become a problem resulting in discomfort and mould. This should be addressed through ventilation; however building envelopes can also play a role. 'Breathing' wall designs and absorptive materials such as plasterboard located on interior faces can also be used to help regulate internal humidity.

1.12 Colour

The colour and material of the external face of a building influences the extent to which heat from the sun is absorbed or reflected. Darker colours can be used to absorb heat from the sun and warm buildings in winter. In summer, lighter colours reduce the unwanted heat gains from the sun and can be used to help keep buildings cool. Further detail can be found under 'Cool roofs' below.

1.13 Green walls

Creepers can be grown up walls. These have the advantage of increasing vegetation and the environmental work carried out by plants, such as humidity and temperature control, carbon dioxide absorption and oxygen production. In addition, creepers and vegetation close to the envelope help increase the size and stability of the external air film thereby increasing R-values. Deciduous creepers can also be used to respond to changing thermal requirements of building envelopes. In summer, the relatively lighter colour of leaves and the still external air film created can be used to help keep buildings cool. In winter, when leaves drop off, the darker colour of walls can be exposed and the sun used to warm the building.

1.14 Glazing and windows

The design, specification and location of glazing and windows are a very important aspect of energy efficient, comfortable buildings. In particular the following issues should be considered:

- **Area of glazing:** The area of glazing on a façade should be an optimal balance between daylight quality and heat gains and losses through the envelope. Glass generally has a much lower R-value than solid walls. Therefore in highly glazed areas it may be difficult and expensive to control heat gains and losses. Where areas are highly glazed, high performance glazing should be investigated (see below).
- **Location:** Where possible, windows and glazing should be avoided on east and west facades to avoid unwanted heat gains. Windows should also be placed where they will provide a good view and higher up in walls to support good day lighting.
- **Opening sections:** Naturally ventilated buildings should have an equivalent opening area (of windows or doors) of at least 5% of the floor area. In warmer areas this may be increased to above 10%. Windows with opening sections at both high and low level benefit from being able to use the stack effect to create air movement and can be used to vent hot air out of the top of rooms and draw in cooler air in at low levels. In buildings where cross ventilation is being used as a cooling strategy, air movement should be directed around people and the 'breeze path' between windows on opposite walls be made a direct as possible to ensure that air movement is effective.
- **Controls:** Window opening controls should be designed to give occupants control over their local environment. This can be done by having regularly spaced windows and providing at least one opening section per 5 m of façade.

1.15 Glass

More sophisticated glazing should be used where high performance is required. The following characteristics of glass can be used to promote energy efficient design.

- **Visible light transmittance:** Glass with high light transmittance supports good daylight within buildings, reducing the requirement for artificial lighting.
- **Solar heat gain coefficient:** This is the proportion of total solar radiation that is transferred through the glass at normal incidence. Glass with lower coefficients reduce the amount of heat gain from the sun.
- **U-values:** Increasing U-values, for instance by using double glazing, reduces heat losses and gains.

1.16 Solar shading

Unless sunlight is being used as part of a passive solar strategy, direct sunlight through windows should be avoided to minimise unwanted heat gains. The most effective way of doing this is through solar shading. Different strategies can be used depending on the orientation of glazing. Equator facing glazing should have horizontal shading devices and east and west facing glazing should have vertical shading devices. The design of the shading device should be designed to cut off unwanted sunlight on facades and be based on modelling or calculations of conditions throughout the year. This relatively simple to do and can be carried out using solar charts available from the CSIR or CAD modelling software.

1.17 Light shelves

Light shelves can be used as part of glazing to ensure that areas deeper in buildings receive daylight. In order to ensure that these are effective, designs should be modelled to ascertain impact on daylight quality. Light shelves should also be easy to clean and avoid bird nesting if they are to remain effective.

1.18 Doors

Doors are often a source of uncontrolled air movement in and out of buildings. This can affect comfort and energy efficiency. Lobby areas and self-closing and revolving doors can be used to help reduce air movement.

1.19 Green roofs

Green roofs are increasingly popular as they have a number of advantages over conventional roofs. These are described below:

- **Runoff:** Green roofs can be used to absorb and store rain water, reducing peak flows and the overall amount of run-off.
- **Evaporative cooling:** Moisture from soil and transpiration from planting on roofs can be used to help cool and humidify air, reducing the need for mechanical cooling.
- **Thermal insulation:** Green roofs provide very good insulation, reducing heat gains from the sun in summer and heat losses from the interior in winter.
- **Ecological value:** The ecological value of the site can be improved by using green roofs. Green roofs that extend over the full footprint of the building help ensure that the ecological value of a site is retained or even possibly improved.
- **Amenity value:** Roof gardens can be used to provide pleasant, easily accessible, outside spaces with views for people working or living in high rise buildings.
- **Urban heat island:** Green roofs can help reduce the urban heat island effect by reducing heat build-up in cities.

Green roofs however are still relatively rare and care should be taken in their design and specification. In particular the following issues should be carefully considered: structural loadings (to take into account soil, water, vegetation and people loadings), soil mixture and depth (to retain moisture and sustain plant life), waterproofing and drainage design (to avoid leaks and retain moisture) and appropriate planting schemes (to control maintenance requirements and to ensure year-long attractive appearance).

1.20 Cool roofs

The colour and material of a roof has a significant effect on the extent to which heat from the sun is absorbed in buildings. The choice of colour and material can reduce unwanted heat gains in the building avoiding, or reducing, the need for mechanical cooling. Typical colours and their absorptance values, from SANS 204, are shown below. In general, a target absorptance value for of 0.55 or less should be aimed for.

Colour	**Absorptance value**
Slate (dark grey)	0.90
Red, green	0.75
Yellow, buff	0.60
Zinc aluminium – dull	0.55
Galvanised steel	0.55
Light grey	0.45
Off white	0.35
Light cream	0.30

1.21 Rainwater

Most roofs can be used for rainwater harvesting. This is however is easier to do in simple roofs where water tanks can be fed from a limited number of outlets. Rain harvesting is most effective in roofs constructed of impervious materials with a moderate pitch. For more detail on rainwater harvesting refer the section on Water.

1.22 Renewable energy

Building envelopes can be used to support the generation of renewable energy. Photovoltaic panels and solar water heaters can be integrated into roof designs reduced material use as panels can be used for both weather protection and to generate energy.