Landscape and architectural devices for energy-efficient South African suburban residential design

by

Johan Bothma

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Study leader: Prof. Gwen Breedlove

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Abstract

The study relates international knowledge of climatically responsive and energy-efficient design to work done in South Africa. It also explores the relevance of design devices from international regions to the climates of this country. The research approach explores existing analyses of the main climate regions and the effects of climate factors on human comfort in each, in order to derive appropriate design solutions for the climate of South Africa.

In South Africa obstacles exist in the face of energy efficiency. The cheapness of electricity to the consumer and the virtual non-existence of appropriate legislation appear to be two of the most significant obstacles. Design and subsequent construction of suburban residences is carried out with little regard for climatic context. Water is shown to be a particularly scarce and unevenly distributed commodity, which the affluent have greater access to and consume in greater quantities. However, it is demonstrated that the South African climate is virtually ideal for several climate-responsive energy-efficiency techniques. Especially due to the high solar radiation levels there is potential for various active and passive solar design techniques and technologies.

The impact of atmospheric temperature and humidity, wind, radiation and precipitation on human comfort is investigated. Humidity and wind are demonstrated to be very influential on human comfort, whereas radiation and wind are the most easily manipulated through design. Furthermore, the specific topography and location of a site can influence the microclimate and solar access of an area to a significant degree.

The South African climate is predominantly either hot semi-arid or temperate. Most of the western interior is hot arid whereas the eastern interior and highveld is predominantly temperate, with temperatures increasing to the north and decreasing to the south. The only cool region of the country is found in the highlands of the Drakensberg, with a significant portion of the eastern coast being hot humid.

Methodologies and guidelines for both layout, or macro design, and detailed design of residential suburbs are explored. The manipulation of solar radiation, sunlight and wind, as well as the management of rainwater and used household water is explored. It is shown that

designing suburbs to create access to solar radiation forms the basis of solar design, with solar access control, material and surface treatment largely determining the success of individual designs. Wind manipulation is achieved mainly through planting design, influencing mostly heat loss and gain ratios into buildings. Effective household water management can substantially reduce its consumption. Further research is needed in all aspects of climate-responsive design, especially classification of the South African climate and development of design techniques adapted to this context.

Keywords

Climate, residential, design, energy efficiency, material, construction, site, layout, orientation, topography, hot arid, hot humid, temperate, cool, building, landscape, architecture, solar radiation, ventilation, irrigation

Opsomming

Hierdie studie bring internasionale kennis oor klimaat-sensitiewe en energiedoeltreffende ontwerp in konteks met soortgelyke werk deur Suid-Afrikaners. Die studie ondersoek ook bestaande ontledings van die hoof-klimaatstreke en die uitwerking van klimaatfaktore op menslike gemak. Sodoende beoog die studie om gepaste ontwerpoplossings vir die klimate van die land voor te stel.

Verskeie struikelblokke bestaan in die pad van energiedoeltreffendheid in Suid-Afrika. Die lae prys van elektrisiteit en afwesigheid van minimum regulasies blyk twee van die belangrikstes te wees. Ontwerp en konstruksie van voorstedelike wonings geskied sonder inagneming van klimatologiese konteks. Water blyk ook 'n besonders skaars hulpbron te wees. Daar is groter toegang daartoe in meer gegoede en word daar in groter hoeveelhede gebruik. Dit word egter getoon dat Suid-Afrika se klimaat hoogs geskik is vir klimaat-sensitiewe ontwerp, veral vanweë die hoë vlakke van son energie, aanwendbaar volgens beide aktiewe en passiewe benaderings.

Die belangrikheid van atmosferiese temperatuur en humiditeit, wind, son energie en neerslag op menslike gemak word ondersoek. Humiditeit en wind blyk die grootste invloed op menslike gemak uit te oefen, terwyl son energie en wind die optimaal deur ontwerp gemanipuleer kan word. Verder speel die spesifieke topografie en ligging 'n belangrike rol in die mikroklimaat van 'n terrein.

Die Suid-Afrikaanse klimaat is oorwegend of warm en semi-aried, of gematig. Meeste van die westelike binneland is warm-aried, terwyl die westelike binneland en hoëveld gematig is, met 'n gemiddelde toename in temperature na die noorde. Die enigste koel streek is te vinde in die Drakensbergse hoogland, en 'n beduidende deel van die Ooskus is warm en vogtig.

Metodologieë en riglyne vir uitleg, grootskaalse ontwerp en detailontwerp van residensiële woonbuurte word ondersoek. Die manipulasie van uitstraling, sonlig en wind, sowel as die bestuur van reënwater en huishoudelike afloop word aangespreek. Daar word gewys dat toegang tot sonlig die basis vorm vir woonbuurte wat vir son energie benutting beplan word, terwyl beheer van sonlig, keuse van materiaal en oppervlakbehandeling die sukses van

individuele ontwerpe bepaal. Windbeheer word hoofsaaklik toegepas deur plantontwerp en strukturele elemente, deur die verlies van hitte en opname deur geboue te beheer. Effektiewe residensiële waterbeheer kan die gebruik daarvan dramaties verminder. Daar word ook getoon dat meer ondersoek na veral die klassifikasie van die Suid-Afrikaanse klimaat, ten opsigte van klimaat-sensitiewe ontwerp, en die ontwikkeling van ontwerpriglyne in daardie konteks nodig is.

Sleutelwoorde

Klimaat, residensieel, ontwerp, energie doeltreffend, materiaal, konstruksie, terrein, uitleg, oriëntasie, topografie, warm en aried, warm en humied, gematig, koel, gebou, landskap, argitektuur, uitstraling, ventilasie, besproeiïng.

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List of abbreviations

ASLA: American Society of Landscape Architects Foundation

BTU: British thermal unit

CSIR: Council for Scientific and Industrial Research

DBSA: Development Bank of Southern Africa

DEAT: Department of Environmental Affairs and Tourism

DI: Discomfort index

DME: Department of Minerals and Energy

DWAF: Department of Water Affairs and Forestry

GWh: Gigawatt hours

IDRC: International Development Research Centre

ISES: International Solar Energy Society

kWh/m^2: kilowatt hours per square metre

MW: megawatt

NBRI: National Building Research Institute

RH: Relative humidity

SABS: South African Bureau of Standards

SBAT: Sustainable building assessment tool

SEED: Sustainable Energy for Environment & Development Programme

SHI: Sustainable Homes Initiative

UN: United Nations

WHO: World Health Organisation

W/m^2: Watt per square metre

Glossary of terms

Albedo: The ratio of reflected solar radiation to the total incoming solar radiation where both streams are measured across the complete wavelength range of solar radiation.

Built windbreak: A built structure such as a fence or wall that is designed and placed to reduce the speed of oncoming wind on its downwind or leeward side.

Climate/climatic region: A generic term used in this study to indicate any geographic area with common climatic characteristics.

Discomfort Index: A system used by weather services to determine how uncomfortable certain combinations of temperature and humidity are to humans, determined by the equation $(2 \times T) + (RH/100 \times T) + 24 = DI$ where: T = temperature in °C, RH = relative atmospheric humidity and DI = discomfort index.

Embodied energy: Energy associated with the production, transport and storage of materials in construction that is "hidden" and not directly associated with the building process itself.

Emissivity: The degree to which a real body approaches being a perfect absorber and emitter of radiation.

Energy efficiency: Using energy and the resources used in its production in ways that eliminate unnecessary or avoidable waste.

Life-cycle costs: The comparison of the capital expenditure used to create the system compared with the savings in money that arise from reduced fuel use.

Shelterbelt: A structure that is composed of plants and designed and placed to reduce the speed of oncoming wind on its downwind or leeward side.

Skyspace: The solar access zone or portion of sky north (in the southern hemisphere) of a collector that must remain unobstructed by objects that block solar radiation, in order for a solar collector to function optimally.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Windchill factor: The process through which wind augments the convective heat loss through the skin, resulting in a temperature being perceived as being lower than the ambient atmospheric temperature. This phenomenon is especially pronounced under cold conditions.

Windbreak: A generic term used in this study to indicate both built windbreaks and vegetative windbreaks or shelterbelts.