CHAPTER 9

THERMAL EFFICIENCY & COMFORT ACHIEVED WITH MASONRY WALLING

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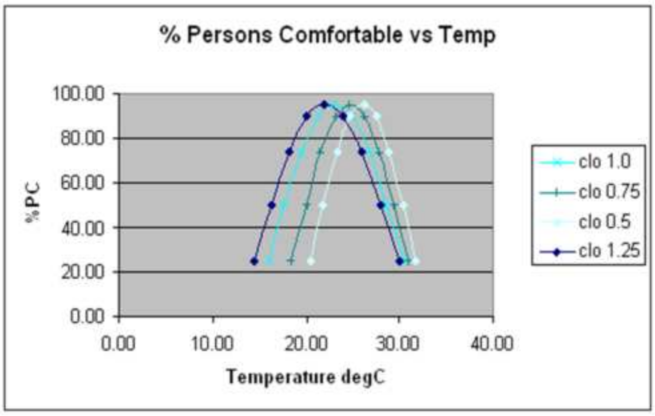
Human Comfort & Adaptive Theory

'Thermal comfort is that state when a certain proportion (80-90%) of respondents surveyed under varying temperatures, humidity, radiant heat, clothing and air movement indicate that they are most comfortable'.

This fundamental research was performed by Professor P.O Fanger who developed the equations linking human comfort to thermal environment.

Fanger produced an index of responses to temperature, which can be translated into the percentage of persons satisfied at each temperature. This work is now incorporated into recognised international standards, such as ISO 7730: 1994 and the ASHRAE Standard 55.

Comfort graphs are developed for sedentary persons at various clothing resistance levels (clo), and are expressed as the Percentage of Persons Comfortable vs. Temperature – as per Figure 9.1

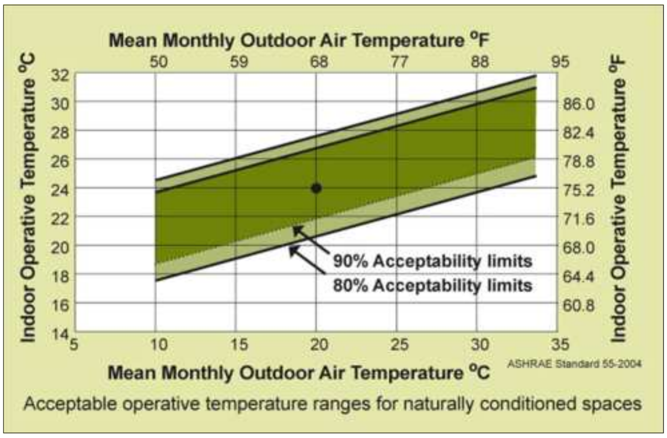


9.1 - The relationship between % persons comfortable and average temperature

For naturally ventilated buildings the thermal comfort range is a range ± 7˚C above or below the temperature, which has been set as the Thermal Neutrality Temperature for that region.

The Thermal Neutrality temperature varies from region to region due to the ability of humans to adapt to local climate conditions.

It is intuitively obvious perhaps, that humans, like other mammalian species, adapt to cooler temperatures in winter and the opposite in summer, such that people living in the hotter regions are able to tolerate the higher temperatures more naturally compared to those living in the colder/elevated localities that are able to function normally despite the very low temperatures. Figure 9.2 expresses these observations graphically, as per the mathematical relationships developed by Schokolay & Elluciems.



9.2 - The range of human comfort temperatures

Benefits of Providing Comfort in Buildings

An immediate benefit of good thermal design for house and building occupants is improved health, which results directly from improved thermal comfort levels.

Improved comfort in buildings will also generate heating or cooling cost savings, due to building occupants requiring less energy to heat or cool their surrounds when they are comfortable. This reduction in energy consumption translates directly into a reduction in greenhouse gas (GHG) emissions.

The poor standard of thermal performance in low income and informal housing in South Africa has been identified by researchers as disproportionate to the expenditure required for heating/cooling energy by the underprivileged as result of these low standards. The financial wellbeing of this community can be improved, through efficient thermal design to meet the required comfort standards.

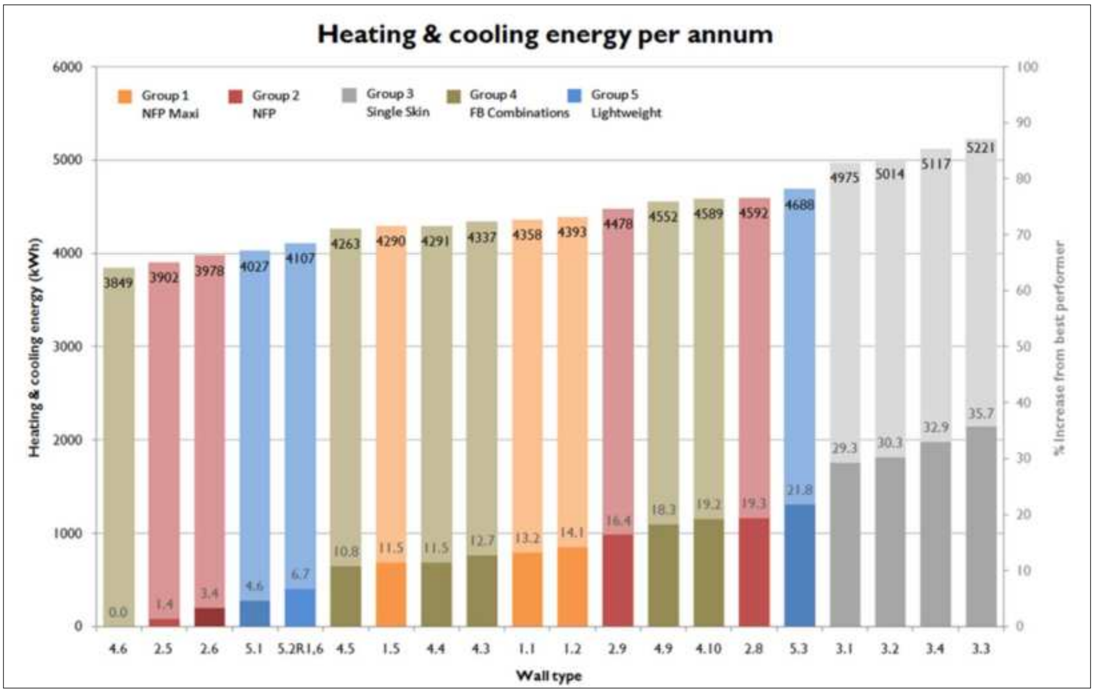
The Clay Brick Association of South Africa has conducted independent research which proves that buildings with optimised thermal performance in the walling, and constructed with clay brick, as well as the appropriate levels of thermal resistance, will consume less heating and cooling energy and are the cheapest for occupants to run.

Building Human Comfort into Building Designs

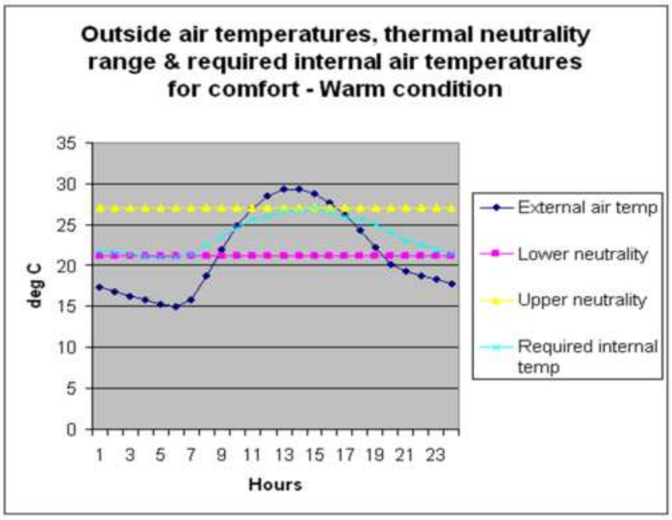
Design strategies that ensure interior air temperatures are within 80% of the human comfort range can be developed using thermal resistance and the thermal mass of walls and floors.

The fluctuation or swing in temperature within a house can be restricted to be within the range of thermal comfort for any region. If this is achieved, the heating requirement can be minimised in winter, with the hot peak temperatures maintained below the upper limits of summer thermal comfort.

The target or maximum daily temperatures permissible or necessary to ensure that indoor temperatures are within the recommended comfort range/s should be incorporated into the



9.3 - Energy usage in housing for various walling solutions, WSP Green-by-Design



9.4 - The range of temperature fluctuation about the comfort range

building design, so as to minimise energy usage. This target swing can be calculated from the building design and materials specification using the CR Method, which is built into SANS 204: Energy Efficiency in building, or by using computer energy modelling techniques.

Important in achieving the above objective is to ensure that the walling, flooring and ceiling surface temperatures are on average or close to the same air temperatures. This is the required Mean Radiant Temperature (MRT), which can be achieved with the requisite thermal resistance and thermal mass designed into these elements.

The importance of maintaining the MRT close to the desired air temperature is as result of the fact that human comfort is 2/3 the radiant effect and 1/3 the conductional and convectional effect of air temperature.

Passive Design Strategies for the various RSA Climates

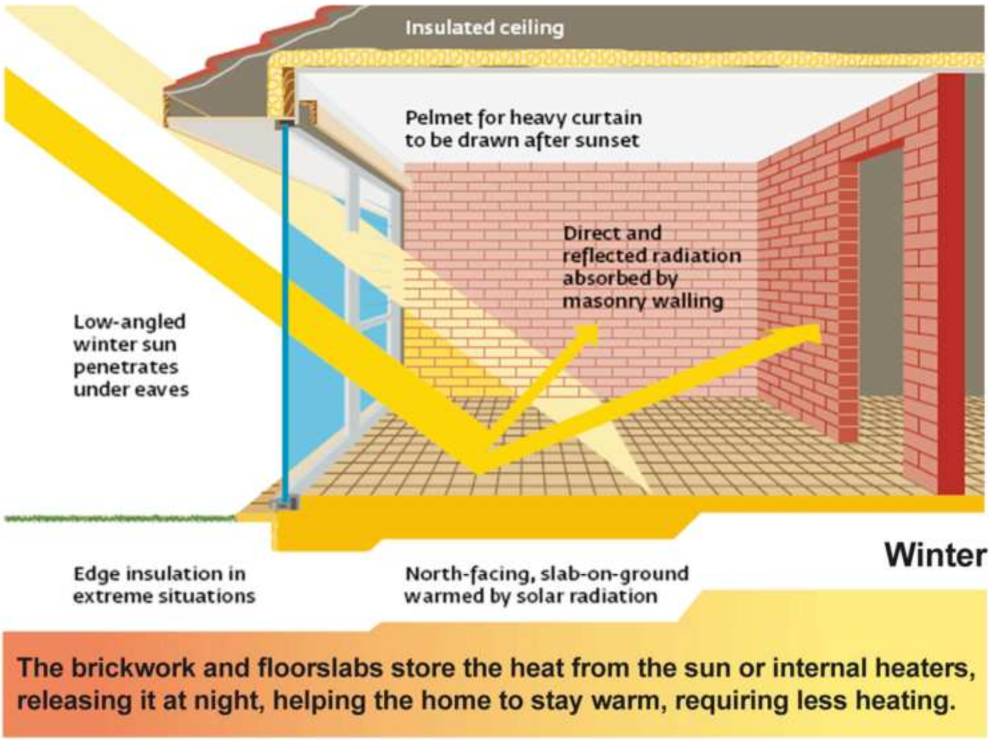
If the design objective is to build an 80% persons comfortable standard in housing in South Africa, it would imply that houses at all times are within the limits of Thermal Neutrality for a particular region. Buildings with a daytime occupancy might have a lower requirement.

Under winter conditions, the range of Thermal Neutrality for most elevated and southerly locations in South Africa is (with acclimatisation) above the range of daily temperature fluctuation. Therefore, advantage needs to be taken of warming via solar radiation entering via windows.

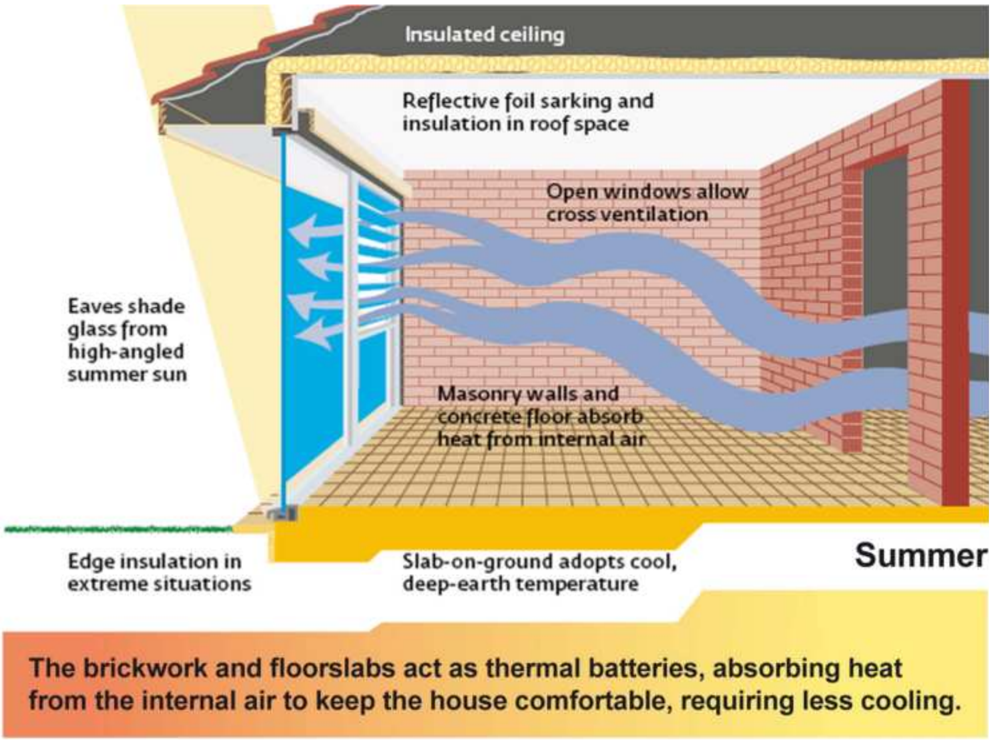
Heating is necessary to bring occupants to human comfort levels, except for the Eastern coastal belt, and for the Lowveld and Limpopo valley region. With adequate ceiling insulation, optimal design of the windows and by adding wall insulation to the cavity, thickening North facing walls and by making use of perimeter insulation heating is reduced.

Under hot conditions, in many temperate South African climates, the range of Thermal Neutrality is within the daily range of temperature fluctuation. In these regions interior comfort can be achieved simply by reducing the amplitude of fluctuation in temperature within the structure, by means of :

- Adding insulation in the ceiling
- Incorporating heavy elements such as Clay Brick walling
- Introducing night cooling/ventilation, by adding wall and perimeter or foundation insulation
- Excluding solar radiation with the shading of windows.



9.5 - Winter Passive Solar Design solutions



9.6 - Summer passive design solutions

Thermal Resistance (R-value)

Building elements, particularly those in the shell of a structure give protection from the outside environment, and from extremes of hot and cold temperature. The measures of how effectively the shell of a building maintains an equable temperature for the benefit of occupants is in part via the Thermal Resistance of the shell.

R-value:

In mathematical terms the Thermal Resistance of an element is the inverse of the Thermal Transmittance; i.e.

$R = 1/U$ and $R = d/k$;

Where:

R is the Thermal Resistance of an element (m^2K/W)
d is the thickness of the element and
k is the thermal conductivity
(See Technical Note 6 for further explanation)

The Thermal Resistance of a building element or materials provides that the flow of heat always from hot to cold) is impeded. This impedance is measured in terms of the total R-value for a building element, which is the sum of all component R-values of the various materials, the inner and outer air surfaces and any airspaces that make up the composite building element.

The range of R-values for different walling types are as follows:

Double Clay Brick solid wall	0.35 m^2K/W
Double Clay Brick Cavity Wall	0.60 m^2K/W
Double Clay Brick Wall with thermal insulation contributing R=1.0 in the cavity	1.35 m^2K/W

Further discussion on the adequacy of these R-values is provided in Chapter 3.

The thermal insulation materials capable of providing an R=1.0 level of thermal resistance are elaborated on in Technical Project # 1: Masonry Insulation Solutions.

The following will meet the above requirement:

40mm of Expanded polystyrene (partial fill)
30mm of Extruded polystyrene
25mm of Polyurethane foam board (with vapour retarder facing)

These products should be fixed to the inner wall leaf via penetrations of the wall ties.

Thermal Mass or Thermal Capacitance

Thermal Mass is a concept in building design that describes how the mass of the building provides "momentum or inertia" against temperature fluctuations.

The Thermal Mass of a wall absorbs heat (thermal energy) when the surrounds are higher in temperature than the wall mass and gives heat (thermal energy) back when the surrounds are cooler.

Scientifically, thermal mass is similar to specific heat, capacitance or heat capacity.

Thermal Capacity is typically referenced by the symbol 'c' and measured in units of J/kg K [J= Joules of heat energy and K = Degrees Kelvin].

Heat Storage Capacity of a building element or material is represented by the equation:

$$Q = m \times \Delta T \times c$$

Where:

Q = is the thermal energy transferred,
m =the thermal mass of the body
ΔT= is the change in temperature.

C-value:

It is convenient to express the heat-storing capacity of the envelope in terms of the building shell area, i.e. external walls as these are generally the major contributors to the total capacity, and are unlikely to be compromised by wall covering as may be the case for floors, and this we can refer to as the C-value of the walling.

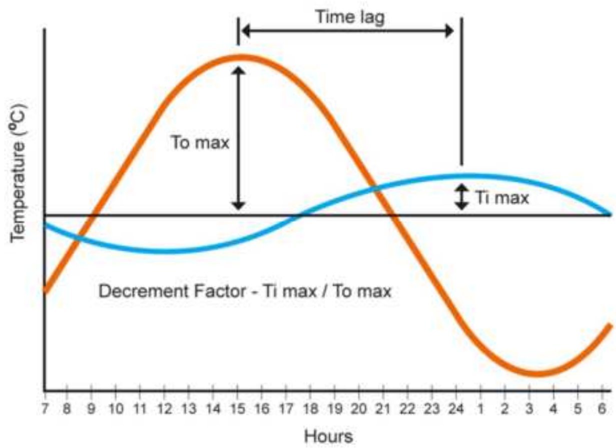
CR-value:

The rate of heat transfer through the element (wall or layer within a wall) is determined by the Thermal Diffusivity which is a combination of the Thermal Resistance and the Thermal Capacity, and equates to the CR-value as developed in SANS 204, and which may be used as a rational design for energy efficient walling.

The CR-Value is conveniently calculated using the product of the calculated R-value and C-value i.e. the Thermal Transmittance and the Thermal Capacity per square meter of the shell of a structure, with a factor to translate the kilo-second units to hours.

$$CRs = Cs * Rs* 0.2777$$

In the following Chapter the application of the CR-value as per SANS 204 is discussed.



9.7 - Graphical illustration of CR-value effects

In the above graph, the orange and blue - 'Internal Temperature Fluctuation' and 'External Temperature Fluctuation' depict how Thermal Mass / Thermal Capacitance of a mass enhanced walling envelope can serve to flatten out the daily external temperature swings.

Thermal Mass is effective in improving building comfort in places where average diurnal temperature swings exceed 7°C as is found in South Africa's six major climatic zones.

NOTES