Criteria for the thermal performance of buildings

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Introduction

This section of the Agrément performance criteria has been written following the work and submissions of TEMM International (Pty) Ltd, who were commissioned to update the method and criteria for evaluations of the thermal performance of innovative building systems.

While this section largely follows the scope of previous Agrément publications, it has been brought into line with research and recommendations by TEMM International.

The information set out in this section is of necessity fairly technical and should help innovators and developers. It is not intended to be for the end user who may not be technically inclined.

The thermal performance of a building may be defined as the result of the process whereby the design, layout, orientation and construction materials of the building modify the prevailing outdoor climate to create the indoor climate. In a house this is generally perceived by the occupants in terms of the extent to which the house seems cool in the heat of summer and warm in cold winter weather, taking into account the amount of heating or cooling required to create comfortable thermal conditions.

Thermal performance can be expressed in numerical or quantitative terms in various ways. The information evaluated is used by Agrément South Africa to arrive at:-

- maximum indoor temperatures in summer
- the amount of energy required to maintain a minimum temperature throughout the winter months.

Maximum indoor temperatures are expressed in degrees Celsius.

The energy required to maintain a minimum temperature (16 °C) throughout the winter months is expressed in kWh/m^2 year.

Since the starting point of a thermal performance evaluation is the outdoor climate which varies from place to place, an evaluation should be specific to one location. For the sake of simplicity , the comparative maximum indoor air temperature in summer is assessed for a house situated in Cape Town, in Durban and in Johannesburg, since these cities are considered to be representative of the climatic regions of the country where most of the population lives.

The energy required to maintain an indoor air temperature of 16 °C in winter is assessed for a house situated in Cape Town and in Johannesburg. Durban is omitted from this assessment as heating of houses in this area of the KwaZulu-Natal coastal region of South Africa is not necessary.

Heat absorbing capacity and thermal insulation

Two properties of a building have a major influence on its thermal performance: its heat absorbing capacity and the thermal resistance of its shell. The values for each of these varies from one construction material to another (eg burnt clay bricks, timber, steel, concrete, etc) and the way in which the material is used (ie cavity or solid walls, single or double glazing, etc).

The heat absorbing capacity of a building element depends partly on its mass and the density of the material from which it has been made. The greater the density and hence the mass of the external and internal walls, the more heat can be absorbed.

The insulating properties of a material or building element depend on the extent to which it limits the transmission of heat through it. The ability of a building component such as a wall to transmit heat is expressed as the U-value of the component.

The heat absorbing capacity and the insulating property of each material used determines the heat storage capacity of a building.

The relative importance of each of these properties in providing a pleasant indoor thermal environment depends on the climate of the area in which the building is erected. In cold and cool climates, buildings with low U-values (ie where heat will not pass through the external walls and roof to the outside easily) will be easier to heat and to maintain at comfortable thermal levels than buildings with high U-values.

In dry areas with wide diurnal variations in outdoor temperatures, a building with a greater heat storage capacity will tend to even out the effect of the outdoor fluctuations in temperature by absorbing and storing heat during the day without passing much of the heat to the inside of the building, but gradually losing heat to the indoor and outdoor environment at night.

In areas with warm humid climates and with small diurnal variations in outdoor temperatures, where solar radiation intensities are high, buildings with a low heat storage capacity, but with adequate insulation, will be preferable. They will tend to cool down faster during the night thus promoting restful sleep.

As a number of different construction materials with different thermal properties are used in a building, an assessment of probable thermal performance takes into account the relative contribution of each of the materials used in its construction, in each of the above mentioned cities.

The U-value of building components is defined as the amount of heat transmitted in watts per square metre per degree Celsius difference in temperature between air on one side of the component and air on the other side of the component. The U-value, therefore, takes into consideration the thermal transmittance of both surfaces of the component as well as the thermal transmittance of individual layers and air spaces that may be contained within the component itself.

For more information regarding thermal performance, the reader is referred to:
Van Straaten, J F (1967). *Thermal performance of buildings*. Elsevier Architectural Science Series. Elsevier Publishing Company, Amsterdam, London, New York

The U-values of typical walls are given below to show how these vary for different types of wall construction.

Type of construction	**U-value** (W/m^2°C)
270 mm thick imperial brick cavity wall (110-50-110) plastered on the interior face	1,7
230mm thick imperial brick solid wall plastered on both sides	2,1
150 mm thick hollow concrete block wall bagged both sides	3,2
140 mm solid concrete brick plastered externally	3,7
82 mm thick insulated lightweight wall: steel frame clad on both sides with 9 mm thick unpressed fibre-cement sheets and the 64 mm space between sheets filled with mineral wool insulation	0,6
82 mm thick insulated lightweight wall: steel frame clad on both sides with 9 mm thick unpressed fibre-cement sheets and 25 mm thick mineral wool insulation in 64 mm space between sheets	1,0

Thermal acceptability and health requirements

The thermal performance of buildings is evaluated with respect to two sets of criteria, viz:

- thermal acceptability
- health requirements

using a computer programme designed for this purpose.

Thermal acceptability

The computer programme is used to calculate the:

- maximum indoor temperatures likely to be experienced under typical hot summer conditions in houses situated in Cape Town, Durban and Johannesburg that are constructed in accordance with the building system under evaluation.
- the energy required to maintain minimum temperature of 16 °C throughout the winter months in these houses in Cape Town and Johannesburg.

All dwellings considered are as follows:

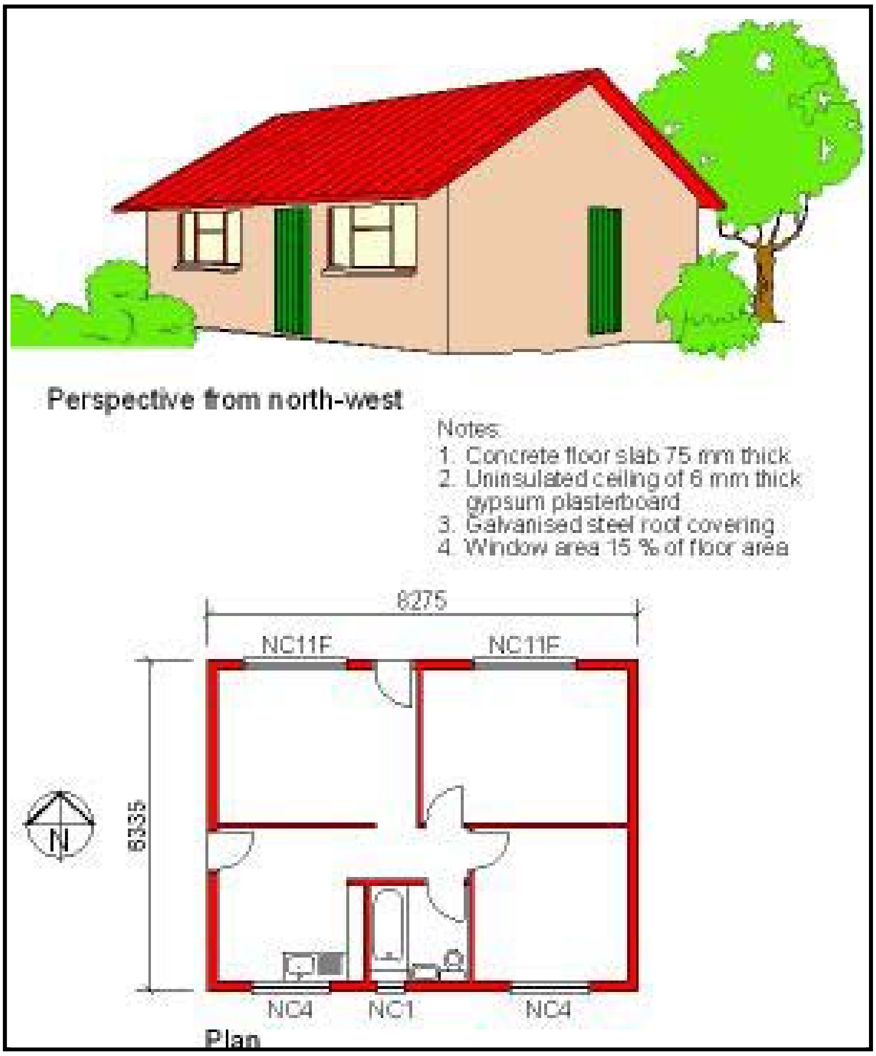
- orientated true north (ie predominant windows of living areas face true north or the longer axis of the building runs as near east/west as possible)
- with an overall floor area of 53 m^2
- with a total window area not exceeding 15 % of the floor area
- with a corrugated steel roof.

The calculations are made for houses with:-

- no ceilings
- 6,4 mm thick gypsum plasterboard ceilings
- ceilings with 40 mm thick glass-fibre or mineral wool insulation, installed above and in close contact with the ceiling.

The results are compared with the assessed thermal performance and energy usage of a 53 m^2 standard brick house.

Standard brick house: a dwelling constructed of 230 mm thick clay brickwork, plastered internally, with a concrete floor and a steel sheeted roof that has a ceiling but no insulation. Orientation and fenestration is as described in the paragraph above.



Standard brick house

The thermal performance of a 53 m^2 house constructed with the building system concerned, is also compared with a similar assessment of a 41 m^2 shack which has a very poor thermal performance.

Shack: a dwelling with walls and roof constructed of unlined steel sheeting, with a concrete surface bed.

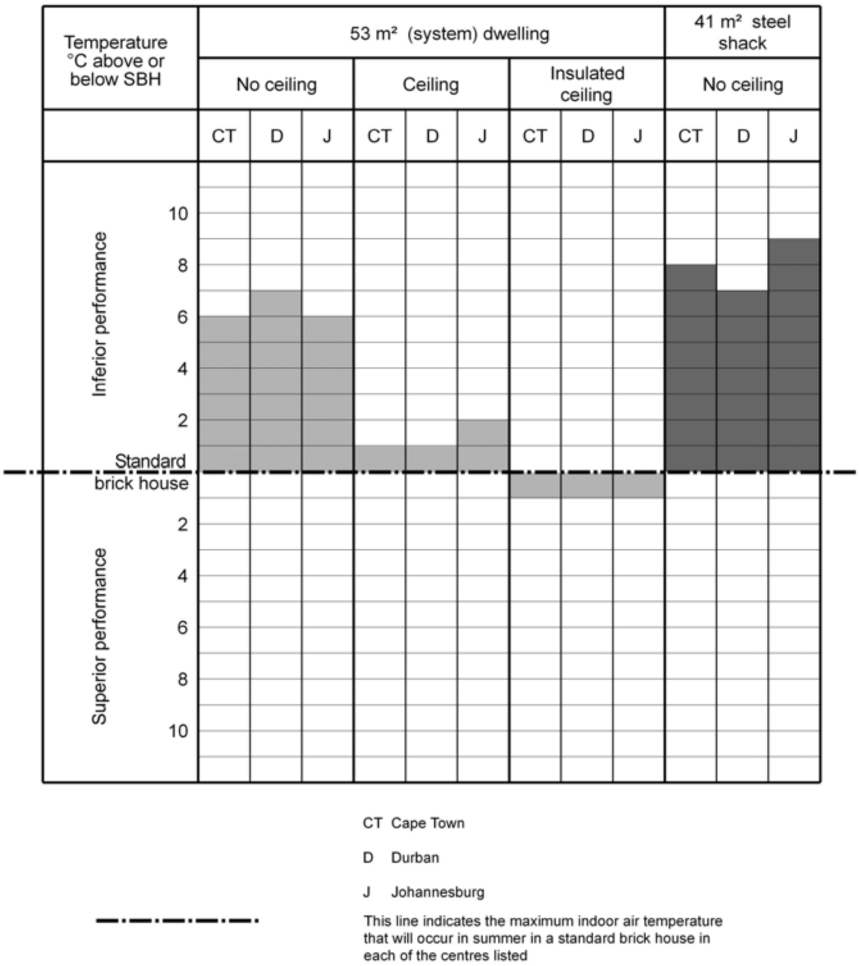
The values obtained for these three types of house construction are tabulated in Agrément certificates. Examples of such tables appear on following pages.

Thermal acceptability criteria

Comparative summer thermal performance

Since the maximum indoor temperature generally occurs in the late afternoon in summer when the occupants are likely to be out of doors or away from home, maximum temperatures are not of cardinal importance. However, Agrément South Africa recommends that action is required to reduce indoor temperatures when these exceed 40 °C, this being the temperature at which a person doing housework could suffer heat stroke.

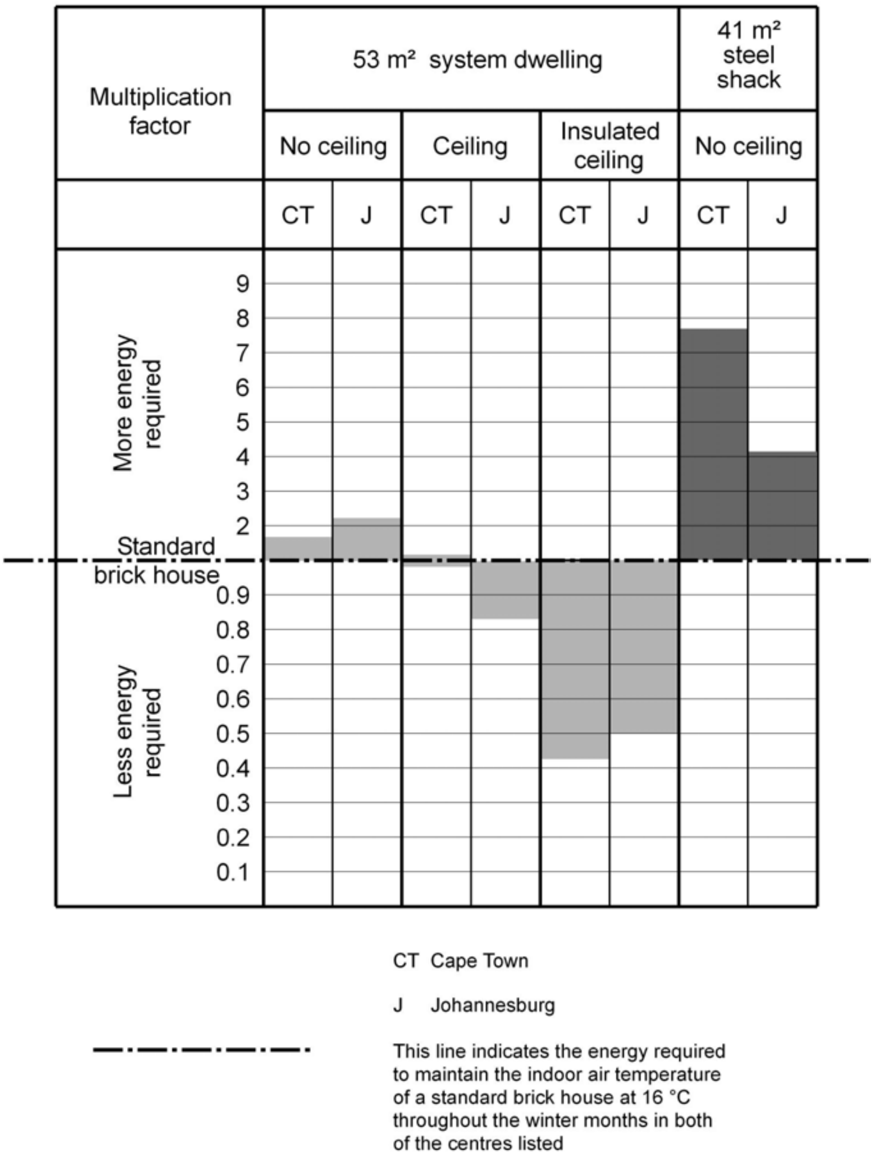
Table 1
Comparative summer thermal performance



Comparative energy usage in winter

The assessed energy (expressed in kWh/m^2 year) required to maintain a minimum temperature of 16 °C in a 53 m^2 house constructed in accordance with the building system, throughout the winter months, is reported in Agrément certificates by means of the multiplication factor by which the energy used is increased or decreased, compared with the 53 m^2 standard brick house and the 41 m^2 shack, of similar orientation and fenestration in both Cape Town and Johannesburg.

Table 2
Comparative energy use



Improving the thermal efficiency of dwellings in general will of course benefit the whole population, but the people who will benefit most from the increased thermal efficiency are those who live in informal dwellings. Research has shown that only 26 % of informal houses are electrified.

The remainder burn bio-fuels of some sort for cooking and heating purposes which results in high levels of indoor and outdoor air pollution. Exposure to this pollution poses a threat to the health of the occupants of these dwellings which can be reduced considerably by improving the thermal efficiency of the house, thus reducing the need to burn bio-fuels for heating.

Acknowledgement

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Certain parts were carried over from earlier publications on Agrément South Africa's criteria